3. Forages

Forages are whole plants harvested for livestock feed. They are an important component of crop rotations on many farms. Forages provide many crop rotation and environmental benefits, including reduced soil erosion, and improved soil health and organic matter. In addition to providing a 100 lb/acre nitrogen credit, research has shown a 10%–15% yield benefit to corn following alfalfa in a rotation.

Forages are a major Ontario crop, providing feed for Ontario's livestock industry. Hay and haylage are grown on 831,000 ha (2,000,000 acres), while there are 239,000 ha (600,000 acres) of seeded pasture and 415,000 ha (1,037,000 acres) of natural pasture. Corn silage is grown on approximately 104,000 ha (260,000 acres). The value of forage production is estimated to be about 10% of Ontario's agricultural production.

Crop management is more complex with forages than with many other crops, for several reasons:

- forages usually consist of a mixture of different species
- forage may be used as either stored feed or pasture
- forage species may include either annuals or perennials
- a wide range of harvest and storage systems are used
- perennial crops require management to ensure over-winter survival

For information on corn silage production, see *Selecting Hybrids for Silage,* Chapter 1, *Corn.* For information on corn silage harvest and storage, see *Haylage and Corn Silage* (this chapter).

For more detailed information on pasture, see OMAFRA Publication 19, *Pasture Production,* available on the OMAFRA website at ontario.ca/crops.

Species

Perennial Legumes

Most legumes grown for forages have taproots and broad, compound leaves composed of a number of leaflets that are arranged alternately on the stem. New shoots originate from the crown of the plant, and the growing point of each shoot is located at the top of the shoot. As a family, legumes produce higher quantities of protein than grasses. Table 3–1, *Characteristics of perennial forage species grown in Ontario,* summarizes the strengths and precautions for perennial forage species.

If properly inoculated, legumes have the capacity to use atmospheric nitrogen, eliminating the need to apply nitrogen from commercial sources. Legumes also supply a considerable amount of nitrogen to the grass portion of the mixture.

Table 3–1. Characteristics of perennial forage species grown in Ontario

Species	Suitability	Persistence (years)	Strengths	Cautions
Legumes				
Alfalfa	stored feed	3–4 S. Ont. 1–4 N. Ont.	• excellent quality • excellent yield	• poor persistence under grazing • low tolerance to acidic or poorly drained soil • rest period helps rebuild root reserves • may cause bloat
Birdsfoot trefoil	pasture stored feed	5+ (may reseed itself)	• high quality • no bloat hazard • good tolerance to acidic & variably drained soil	• slow to establish • slow spring growth and regrowth • unpalatable to horses
Red clover	pasture stored feed cover crop	1–3	• excellent first-year yield • easy to establish • high quality • good tolerance to acidic or variably drained soil	• competitive, especially with other legumes • difficult to dry for hay • stand thins rapidly • may cause bloat • may cause temporary infertility in grazing sheep

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Table 3–1. Characteristics of perennial forage species grown in Ontario

Species	Suitability	Persistence (years)	Strengths	Cautions
White clover	pasture	5+	• excellent quality and palatability • good tolerance to close, frequent grazing	• may cause bloat • low drought tolerance
Grasses				
Timothy	stored feed	5+	• easy to establish • good tolerance to variable drainage • seed is inexpensive • later maturity enables higher nutritional quality	• poor summer regrowth production
Smooth bromegrass	pasture stored feed	5+	• sod-forming rhizomes spread and fill in bare ground • better quality retention with maturity	• large seed size may cause seeding challenges • poor persistence under aggressive cutting schedules (best suited to two-cut systems)
Meadow bromegrass	pasture stored feed	5+	• early spring growth • fast recovery after cutting or grazing • good winter-hardiness • good palatability	• large seed size may cause seeding challenges • sensitive to flooding • spreads less by rhizomes than smooth bromegrass
Orchardgrass	pasture stored feed	5	• very early pasture • excellent regrowth • good drought tolerance • good tolerance to close grazing • very responsive to nitrogen	• rapidly loses quality and palatability with maturity • wide variety differences in maturity • very competitive with other species • poor tolerance to variable drainage and icing
Reed canarygrass	pasture stored feed	5+	• excellent yield on both poorly drained and dry soils • good regrowth • very responsive to nitrogen	• slow to establish • first cut rapidly loses quality and palatability with maturity • poor tolerance to close grazing or frequent cutting
Meadow fescue	pasture stored feed	5+	• more suitable for managed gazing than as stored feed • grows in early spring and late fall • tolerant to variably drained soil • more palatable than tall fescue • prevents erosion in waterways	• coated seed required • very competitive with other species • low drought tolerance • low quality with maturity • less persistent and lower yielding than tall fescue
Tall fescue	pasture stored feed grassed-waterways	5+	• high yield • good summer growth • good feed quality for fall stockpile grazing • good tolerance to acidic soil	• coarse leaves lower palatability in dry hay • use endophyte-free seed
Perennial ryegrass	pasture stored feed	2–3 S. Ont.	• excellent nutritional quality and palatability • establishes very quickly • good tolerance to close grazing	• poor summer drought and heat tolerance • poor tolerance to variably drained soils • variable persistence
Kentucky bluegrass	pasture grassed waterways	5+	• good quality and palatability • good tolerance to close grazing	• low seasonal yield • poor summer production • very slow to establish

Alfalfa

Alfalfa is the highest-yielding perennial forage crop grown in Ontario and the most frequently grown forage legume. It is higher yielding and produces more protein per unit area than other forage legumes. Alfalfa can be grown alone, but is often grown in mixed stands with various grass species. For high yields and persistence, alfalfa requires well-drained soil, a pH above 6.1, adequate fertility and proper harvest management. Well-managed alfalfa normally persists for 3 or more years. The energy and protein levels of alfalfa-based forage are determined by stage of growth at the time of cutting. Alfalfa winterkill management risk factors include fall harvest, aggressive cutting schedules, poor fertility, poor drainage and older stands.

Birdsfoot Trefoil

Birdsfoot trefoil is a non-bloating legume best suited for permanent pasture. It will reseed itself, making it an excellent choice for steep or stony land not suited to cultivation. Although individual plants live for only a few years, stands of birdsfoot trefoil have remained productive for many years when allowed to go to seed. It is well adapted to soils with marginal drainage. Birdsfoot trefoil has a lower yield potential and is more difficult to dry than alfalfa, so it is recommended for hay production only in areas where alfalfa will not grow well. Since birdsfoot trefoil seedlings are slow to establish, at least a year is required to get a satisfactory stand.

Red Clover

Red clover is a short-lived perennial. Yields are good the year after establishment but are often quite low the following year, especially in southern Ontario. It can be grown in fields that are too wet or acidic for alfalfa, and establishes well. It can make excellent quality feed. Red clover is most often stored as haylage or baleage since it is difficult to dry, and often results in dusty or mouldy hay.

There are two general types of red clover grown in Ontario: double-cut or "medium" red clover and single-cut or "mammoth" red clover. Double-cut will flower in the seeding year, with vigorous regrowth after cutting. Single-cut is slower growing and matures about two weeks later than double-cut. Single-cut does not flower in the seeding year or after the first-cut in succeeding years.

Use of red clover as a cover crop has become an important practice on many farms. Refer to Chapter 8, *Managing for Healthy Soils,* for information on the use of red clover as a cover crop.

White Clover

White clover is used mainly in pastures. It is a short-lived perennial that can reseed itself. There are three general types of white clover: ladino, white dutch and small wild white. They are similar in appearance but differ in size, with wild white being the smallest and ladino the largest. White clover has stolons, which are stems that creep on the ground, with branches that are erect or upward slanting. Roots are shallow and fibrous and develop from nodes of the creeping stolons. White clover grows poorly in dry weather, but is relatively tolerant to frequent grazing and has good palatability. White clover can be frost seeded or no-tilled into existing grass pastures to improve forage quality and yield.

Sweet Clover

Sweet clover is a slow-growing biennial, occasionally grown as forage and sometimes used to alleviate compaction. Sweet clover does not flower in the year of establishment. In the spring of the second year, it grows quickly to become a tall, coarse-stemmed plant. The presence of coumarin in sweet clover makes it less palatable to livestock. There are two types of sweet clover: white-flowered and yellow-flowered. White sweet clover is deeper rooted, taller and coarser, which makes it more suitable for plowdown than for forage. The yellow-flowered is more palatable to livestock and more attractive to bees, which makes it more suitable for forage. **Mouldy sweet clover hay may contain dicoumarol, which can prevent normal blood clotting and result in the death of livestock from bleeding.**

Alsike Clover

Alsike clover is a perennial although it is sometimes treated as a biennial. It can grow on soils that are acidic and poorly drained. Alsike produces only one cut of hay per year and is not normally a preferred forage legume. **Alsike clover can cause photosensitivity and liver damage in horses, so it should not be included in horse hay or pasture mixtures.**

Perennial Grasses

Grasses have many long, slender leaves that are borne on a stem. They have very fibrous roots that help bind the soil together, thereby reducing erosion. "Sod-forming" grasses have rhizomes or underground stems that produce new shoots at each node. These grasses are capable of spreading and thickening up a stand. "Bunch-type" grasses do not have the ability to spread by rhizomes, but do produce tillers from crown buds at the base of the plant.

Grass species differ in their competitiveness with legumes. This will influence the grass-to-legume ratio of an established stand. Grasses such as orchardgrass and the ryegrasses tend to be more competitive with alfalfa than timothy or bromegrass. Grasses are lower in protein than legumes when cut at a similar stage of development. Grasses tend to be higher in fibre and fibre digestibility.

Timothy

Timothy is the most widely sown forage grass in Ontario and is commonly grown in mixtures with alfalfa. It is slower to mature than other grass species, making harvest management easier. Timothy seed mixes well with alfalfa seed and flows through the small seed box. It is a bunchgrass with limited tillering ability, which makes it non-aggressive when sown with other species. It is easy to establish in early spring or late summer and is adapted to heavier soils and variable drainage. Timothy is palatable and high yielding in first-cut. Although some varieties have been developed for improved regrowth, regrowth after first-cut and mid-season production is limited, especially in hot and dry seasons. Timothy has poor drought tolerance. For the commercial horse hay market, timothy is the preferred grass species.

Smooth Bromegrass

Smooth bromegrass spreads by rhizomes and the stand can thicken over time. It is slightly earlier in maturity than Timothy. It does not have good persistence under aggressive cutting schedules, but is well suited to two-cut systems. Smooth bromegrass is palatable and tends to retain its nutritional value with increasing maturity better than most grasses. Its large fluffy seed prevents it from flowing through the small seed box of drills. It does not establish well if it is either surface seeded or seeded deeper than 5 cm (2 in.).

Meadow Bromegrass

Meadow bromegrass is similar to smooth bromegrass, but is more useful as a pasture species because of its early spring growth and faster recovery rate after grazing.

Orchardgrass

Most orchardgrass varieties are the earliest maturing of the forage grasses. Orchardgrass quickly loses palatability and digestibility after heading. Newer, later maturing varieties have been developed that match more closely the maturity of other species in a mixture. Orchardgrass will grow much more vigorously in the warm, dry conditions of midsummer than timothy or bromegrass, resulting in more yield and a greater proportion of grass in the second and third cutting of alfalfa-grass mixtures. Orchardgrass is not as winter-hardy as most other forage grass species and will not persist in wet soils. Its aggressive seedlings make orchardgrass easy to establish. Orchardgrass is a preferred species to use in intensively managed pastures, where early maturing varieties work well.

Reed Canarygrass

Reed canarygrass is known for its ability to tolerate poorly drained soils, but can also provide high yields on well-drained soils. It will produce higher yields than other grass species during dry conditions. Reed canarygrass spreads by rhizomes. After heading, it develops coarse stems and leaves, and quickly loses palatability and digestibility. Regrowth is vegetative and does not form a seed head, so second and third cuts can be very high quality. Reed canarygrass is slow to establish, usually contributing little yield for the first two years, so is more suitable in longer rotations.

In the past, livestock have performed poorly on older varieties of reed canarygrass because of alkaloids it contained that resulted in reduce palatability, lower intake, and poor animal performance. Currently recommended reed canarygrass varieties are free of tryptomine and carboline alkaloids. Some varieties are also lower in the gramine alkaloids.

Tall Fescue

Tall fescue is a coarser, leafy, bunch-type grass that is used in pastures, alfalfa haylage mixtures and erosion control. It is not as commonly used in dry hay mixtures. It is adapted to most soil types; tolerates imperfect drainage and withstands animal traffic well. Its ability to maintain good feed quality into late fall makes it useful in fall-saved "stockpile grazing". Endophytes are seed-borne systemic fungi that are linked to poor animal health and performance on some tall fescue pastures. Pregnant broodmares are particularly affected. Once introduced by infected seed, the fungus cannot be controlled in an established stand of tall fescue. To avoid these endophytes in livestock diets, plant endophyte-free varieties.

Creeping Red Fescue

Creeping red fescue is a dense, sod-forming grass that establishes and spreads vigorously on most soil types, including well-fertilized subsoils. Its solid root system and thick, fine top growth make creeping red fescue an excellent grass for streambank or grass waterway protection. It is sometimes used in long-term pastures, but its low-growing habit makes it difficult to cut and unsuitable for hay.

Meadow Fescue

Meadow fescue is a hardy grass used in hay and pasture mixtures. It grows best on deep, fertile soils, but will tolerate variable drainage and low fertility. Meadow fescue yields well during the summer and fall maintaining its feed quality later into the season than most grass species. Meadow fescue has several characteristics that distinguish it from tall fescue. Meadow fescue is shorter, has finer leaves and a shallower root system than tall fescue, and is not as persistent.

Perennial Ryegrass

Perennial ryegrass is a short-lived perennial that comes in turf, pasture and hay-adapted varieties. The pasture-adapted varieties tend to have finer leaves, smaller and more numerous tillers, and are later maturing than the hay varieties. Turf-type perennial ryegrasses contain endophytes, so they should not be used for forage. Perennial ryegrass is early and vigorous in the spring, and grows well into the fall, but is unproductive during the hot, dry summer months. Forage quality is excellent. Excessive top growth of perennial ryegrass can result in winterkill in alfalfa mixtures that are left to over-winter. Perennial ryegrass is not well suited to areas with prolonged ice cover and extreme cold without adequate snow cover.

Festuloliums

Festuloliums are a cross between festucas (Meadow Fescue or Tall Fescue) and lolium (Italian Ryegrass or Perennial Ryegrass). By selection, this can combine the high nutritional quality of ryegrass with the improved winter hardiness, persistence and stress tolerance of fescue.

Bluegrass

In Ontario, two common bluegrasses, Canada and Kentucky, grow on approximately 400,000 ha (1 million acres) of permanent pastureland. In southern Ontario, the shallow-rooted bluegrasses produce lush, palatable growth during the spring but are unproductive during the dry, hot summer. When properly fertilized and managed, bluegrass production can be markedly improved, especially under the cooler climate of northern Ontario. In pastures, they withstand close, frequent grazing and tramping, and re-establish themselves where other species thin out.

Species Selection

Soil conditions and management practices often determine which forage species are most suitable. If selecting a mixture, choose the legume first, followed by the grasses, because legumes are often more sensitive to drainage and pH. Soil conditions, such as slope or stoniness, may make it desirable to seed a legume that has long-term persistence. Figure 3–1, *Soil drainage requirements of forage species,* provides information on legume tolerance to various soil conditions.

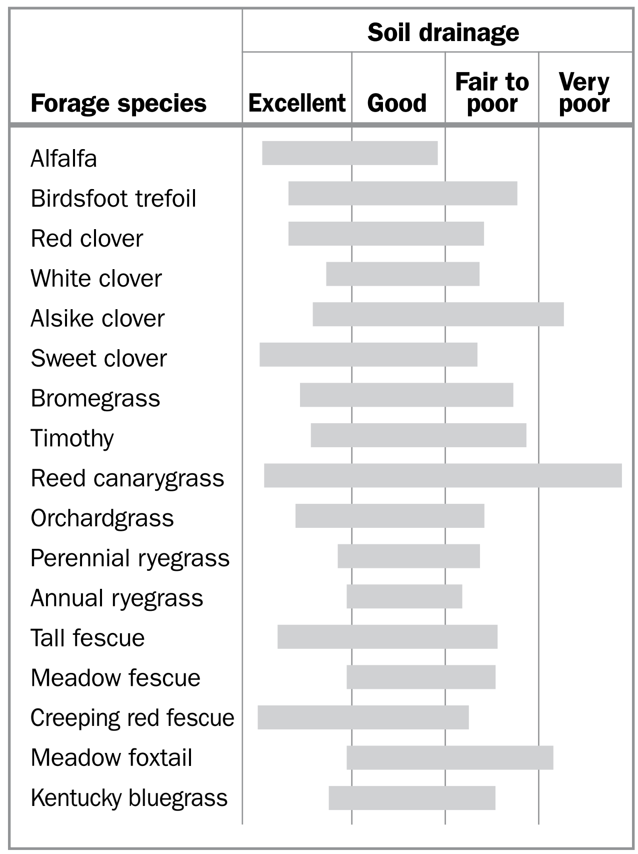

Figure 3–1. Soil drainage requirements of forage species.

Pure stands of legumes, such as alfalfa, are sometimes grown, particularly by dairy producers providing high nutrient quality haylage for their livestock. However, alfalfa and other legumes are more commonly grown in mixtures with one or more grasses. The major advantages of a pure legume stand include:

- higher protein and energy levels of the feed
- a slower decline in nutritional quality with advancing maturity
- little variation in quality from cut to cut

Unless well managed, potential disadvantages of pure legume stands include:

- weedier stands
- complete loss of feed supply if winterkill is severe
- slower drying in the field
- increased lodging
- less palatable feed under some conditions

Grasses are grown in pure stands less often because they are lower yielding without heavy applications of nitrogen. For more information, see *Fertility Management* (later in this chapter). Even with adequate fertility, some grass species produce very low yields under hot, dry midsummer conditions. However, for horse hay or if soil conditions such as poor drainage make mixtures with legumes impractical, pure grass stands can be very productive with proper fertility programs and species selection.

Choosing Species Mixtures

Grass Maturity at Harvest

When selecting the grass, a major consideration should be the maturity of the grass at harvest. When using early heading species such as most orchardgrass varieties and reed canarygrass, harvesting must be early, or quality and palatability suffer. If harvesting will be later, a later-maturing grass such as timothy is more suitable. Since there is a range in maturity among different varieties within many species, consider variety maturity as well.

Desired Grass-to-Legume Ratio

Consider the ratio of grass to legume desired in the mixture. When a lower protein level is acceptable, such as for beef cow, dairy heifer or horse hay, use a higher grass seeding rate for more grass. Higher grass rates tend to reduce weed invasions, particularly by dandelions. If conditions for legume survival are marginal, use higher grass rates for stand insurance. More aggressive grasses, such as orchardgrass, will give more grass in the mixture than less aggressive species, even when similar seeding rates are used.

How Many Cuts Are Planned

Timothy does not crowd alfalfa and under a three-cut system often provides very little forage in second or third cuts. Orchardgrass provides more midsummer grass in alfalfa mixtures than timothy. If a strong grass component is desired in the harvested forage, particularly in second and third cuts, then use orchardgrass, an aggressive grass that will crowd alfalfa as the stand gets older. Bromegrass and reed canarygrass are intermediate in aggressiveness between timothy and orchardgrass, and do not grow well in three- and four-cut systems.

Early or Later Harvest

Management can affect the competitiveness of grasses with legumes. Late harvest, when grasses are in bloom, favours the grasses relative to the legumes. This is particularly true with reed canarygrass. Cut at the boot-stage, reed canarygrass does not crowd legumes. If reed canarygrass is allowed to fully head, it rapidly takes over the stand. Prompt harvest at the grasses' boot stage is particularly important in orchardgrass and bromegrass or reed canarygrass mixtures. If this is not possible or practical, then timothy is a more suitable grass.

Variety Selection

All forage seed sold under a variety name must be labelled "certified seed" and have a blue tag verifying that it is the named variety. Certified seed must meet specific requirements for germination and weed seed content.

Forage seed may also be sold as common seed or as a brand. Common seed and brands may be blends of different seed lots. They must also meet requirements for germination and weed seed content, although the standards are less rigorous than for certified seed. No assurance of characteristics such as disease resistance or hardiness is possible for common seed. Therefore, the performance of stands established using common seed or brands is unpredictable and will often vary from year to year. The use of certified seed, rather than brands or common seed, is strongly advised. Only by planting certified varieties is it possible to know in advance whether the seed planted will provide yield, persistence, disease resistance and maturity. Consult technical variety data from forage seed companies.

Table 3–2, F*orage mixtures for stored feed and pasture*, summarizes the characteristics of the perennial forage species and mixtures grown in Ontario.

Table 3–2. Forage mixtures for stored feed and pasture

LEGEND: S = suggested — = not suggested

Mixture: Seeding Rate[1]	Best Suited for			
	Stored Feed	Managed Pasture	Intensively Pastured	Specific Guidelines
Alfalfa (14 kg/ha)	S	—	—	Only on well-drained fields. Easier to cure as silage than as hay. Harvest at proper stage for high nutrient-quality feed.
Alfalfa (13 kg/ha) + timothy (1 kg/ha)	S	—	—	Increase timothy up to 4 kg/ha for higher grass content and easier curing. Timothy gives stand insurance in areas prone to alfalfa winterkill. For higher nutrient-quality feed, harvest timothy at boot stage.
Alfalfa (11 kg/ha) + bromegrass (9 kg/ha)	S	—	—	Retains quality with increasing maturity better than orchardgrass or timothy mixtures. Bromegrass can thicken stand over time because of its rhizomes but does not have good persistence under aggressive cutting schedules.
Alfalfa (11 kg/ha) + orchardgrass (2 kg/ha)	S	—	S	Better midsummer production than timothy mixture. Select late orchardgrass and early alfalfa varieties. Graze or cut early to maintain quality and palatability. Percentage grass will be higher in all cuts than with timothy or bromegrass mixtures.
Alfalfa (9 kg/ha) + timothy (4 kg/ha) + bromegrass (9 kg/ha) + white clover (2 kg/ha)	S	—	S	Suitable for hay/pasture combinations.
Birdsfoot trefoil (9 kg/ha) + timothy (2 kg/ha)	S	S	—	Use later-maturing timothy varieties.
Birdsfoot trefoil (9 kg/ha) + bromegrass (4 kg/ha)	S	S	—	For long-term stands and early production. Graze early to reduce competition from bromegrass. Good brome growth in fall.
Birdsfoot trefoil (8 kg/ha) + orchardgrass (4 kg/ha)	—	—	S	Good early and mid-season production. Graze down orchardgrass to reduce competition with birdsfoot trefoil. Later-maturing orchardgrass varieties are preferred.
Birdsfoot trefoil (8 kg/ha) + tall fescue[2] (10 kg/ha)	S	S	S	Good production throughout the season. Good tall fescue growth and quality in the fall.
Birdsfoot trefoil (8 kg/ha) + creeping red fescue (6 kg/ha)	—	S	—	Good summer and fall production. Excellent quality in fall.
Red clover (11 kg/ha)	S	—	—	Short-term haylage production or plowdown crop.
Red clover (7 kg/ha) + timothy (6 kg/ha)	S	—	—	Short-term haylage production. When clover disappears, plow or fertilize with nitrogen to maintain production.
White clover (2 kg/ha) + orchardgrass (9 kg/ha)	—	—	S	For pasture use where white clover is adapted. High fertility, adequate moisture and good grazing management required for top production. In dry areas, add alfalfa.

100 kg/ha = 90 lb/acre

[1] Under excellent conditions. For early seeding on a fine, firm seedbed, these rates may be reduced except where coated seed is used.
[2] Use endophyte-free seed.

Annual Forages

There are many options for annual forage crops. They can be part of a planned cropping program or an emergency remedy to provide feed when perennial forage crops are winterkilled or in short supply. Annual forages are a valuable source of hay, pasture or silage. The largest annual crop used to provide forage in Ontario is corn, which is harvested as corn silage. For more information refer to the *Haylage and Corn Silage Harvest* sections of this chapter.

Winter Cereals (Rye, Triticale)

Fall rye and winter triticale can provide a "double crop" forage option by planting after the harvest of many crops, including corn silage. Seeded in late summer or fall, they can provide haylage harvested in mid to late May, or can provide fall and early spring grazing. After the cereals are completely killed with glyphosate or tillage, they can be followed by late-planted crops, such as soybeans or sorghum-sudangrass. Nutritional quality, palatability and intake drop very quickly at the heading stage, so the harvest window is very narrow. Target harvest at the flag-leaf or early-boot stage for high nutrient quality. Rye will mature about 7–10 days earlier than triticale, which enables earlier seeding of the following crop. Apply nitrogen in the spring at green-up to increase yield and crude protein.

Spring Cereals (Oats, Barley, Triticale, Wheat)

Spring cereals are very adaptable for forage production as haylage, baleage or pasture. They are difficult to dry for hay in Ontario. Oats, barley and spring wheat are used extensively as companion crops for perennial forage seedings. They should be harvested as forage to improve the establishment of the perennial forage seeding by removing them as competition. As a double-crop option, spring cereals are sometimes seeded in August following winter wheat or a spring cereal for an early October harvest as silage or baleage.

Many find that an oat forage is the most palatable of the cereals. Early spring planting promotes maximum yields. Nitrogen fertilizer enhances vegetative growth, yield and crude protein, and therefore 55 kg/ha (50 lb/acre) of nitrogen is suggested. Oats normally require about 60 days of growth following germination to reach the boot-stage. Forage quality drops quickly after heading, so harvesting at the boot- to early-heading stage will optimize feed value. Yield will increase as plants mature, but feed quality drops dramatically. At the boot-stage, cereals are typically about 16% crude protein (CP) and 54% neutral detergent fibre NDF with very good fibre digestibility. More information about forage production from spring cereals can be found at fieldcropnews.com.

Cereal-Pea Mixtures

Field peas seeded in mixtures with cereals (oats, spring triticale) will enhance feed nutrient quality. Pea mixtures can increase protein levels and improve forage digestibility assuming the peas make up at least 50% (by weight) of the seed mixture. Adding peas will increase seed costs. Forage pea varieties are preferred. Cereal-pea mixtures may be used as a companion crop for seeding alfalfa but should be harvested for silage. Mixtures of triticale and peas usually have more peas in the harvested forage than mixtures of oats and peas. This tends to increase quality but makes wilting slower and increases the length of time the crop must cure before ensiling. Cut as the cereal is heading out, as the peas will just be starting to pod. If seeded in late April, this growth stage will typically occur around the last week of June. Cereal-pea mixtures can be difficult to wilt and heavy stands can lodge. When used as a companion crop, timely cutting, wilting and removal from the field is important for successful alfalfa establishment.

Westerwold and Italian Ryegrasses (Annual Ryegrass)

Ryegrasses are rapidly growing bunchgrasses that are best adapted to cool, moist conditions, and perform poorly in hot, dry weather. They are higher in nutrient quality than other cool-season grasses at the same maturity. Although sometimes lumped together as "annual ryegrass", Westerwold ryegrass and Italian ryegrass are quite different.

1. Westerwold ryegrass is a true annual that will produce stems and seed heads the year of seeding, and will be winter-killed. Westerwold seed is cheaper and is more commonly used as a cover crop. The Westerwold varieties grow taller, produce stems, and as a result, are easier to harvest for dry hay. They should be cut before or just at the heading stage, since feed quality decreases rapidly after heading.

2. Italian ryegrass is actually a biennial that has a vernalization requirement (exposure to cold temperatures similar to winter wheat) for flowering. The year it is seeded it remains vegetative without a seed-head, producing a lush,

leafy growth with exceptionally high forage quality. When over wintered, it will form a seed-head the following year, therefore harvest timing will be important for forage quality. It can either be spring seeded, or seeded in August. Although there is some risk of winterkill, August seeded Italian ryegrass can provide a late fall harvest and some early season forage the following spring. A single cut can be taken in May, after which the field is replanted to corn silage, soybeans, edible beans or sorghum-sudangrass. An alternative is to keep taking multiple cuts every 4 weeks until the stand becomes unproductive. Harvested correctly, fibre digestibility (NDFd), palatability and intake are exceptionally high, enabling higher forage diets be fed to high producing dairy cows.

Warm-Season Annual Grasses

Members of the sorghum, sudangrass and millet families are semi-arid, tropical, warm-season annual grasses. They are very sensitive to frost in both spring and fall and easily killed. Warm-season annual grasses are sometimes considered in emergency forage situations where alfalfa has winterkilled or when planting has been delayed. They offer advantages over corn silage in that they can be produced with conventional forage seeding and harvesting equipment. They can be used in Ontario for silage (chopped or baleage), green chop or pasture. Sorghums and sudangrass are not recommended as dry hay because they are difficult to cure. Millet is usually harvested as haylage, but with good drying conditions can be made into hay. Millets are preferred over sorghums in some pasture and green chop situations because they do not contain prussic acid. Millets and sorghums can be easily damaged by grazing and therefore should be strip grazed.

Millets

The name "millet" has been given to numerous grass species with small edible seeds. Most millet types, including Japanese, proso, foxtail, barnyard, Koda, finger and Teff, have short (0.3–1.2 m or 1–4 ft), slim stalks. Pearl millet has thicker stalks that are over twice as long (1.5–3 m or 5–10 ft). The millets commonly used for forage in Ontario are pearl millet and Japanese millet. With proper management, millets can produce forage with very good quality. Millets have a smaller stem than sorghums and slightly higher total digestible nutrients (TDN) and protein levels.

Pearl Millet

Pearl millet grows with a mass of very fine fibrous secondary roots and tillers. It exhibits drought tolerance and prefers a lighter sand or sandy loam. Pearl millet can be planted when there is no risk of frost and when soil temperatures are 12°C or warmer. While the last week of May or early June is typically the best time to seed, planting can be delayed until the first of July. The suggested seeding rate is 8–10 kg/ha (7–9 lb/acre) at a 0.5–1 cm (0.25–0.5 in.) planting depth. Growth habits are similar to sorghum-sudan hybrids.

Quality and quantity of forage produced will be determined by the stage of maturity when harvested. For high feed quality, first-cut is usually ready about 55–60 days after planting, when it is still vegetative. Second-cut is ready about 30–35 days later. Leaving at least 10 cm (4 in.) of stubble will result in faster regrowth, however, when grazing, about 15–20 cm (6–8 in.) of stubble should be left for faster regrowth.

The general nitrogen guideline is similar to sorghum-sudan hybrids, split half at planting and half following first-cut if a second-cut is to be harvested. This split application of nitrogen will optimize yield and quality. There are limited weed control options for pearl millet. Refer to OMAFRA Publication 75, *Guide to Weed Control*.

Sorghum Family

Members of the sorghum family used for forage include forage sorghums, sudangrass and various hybrids. There is considerable variability in agronomic and nutritional quality traits among species, hybrids and varieties.

Sorghum and Sorghum-Sudangrass

Forage sorghum and sorghum-sudangrass grow tall and have the potential for high yields. Older forage sorghum varieties were adapted to a high-yield, lower forage-quality, single-cut harvest. Grain sorghums, also called milo, are not suggested for forage production due to low yields.

Newer forage sorghums have been developed to be grown as short season, multiple-cut, high-quality forage. Forage sorghums have fine fibrous secondary roots and tillers, giving them good drought tolerance. Forage sorghums will tolerate heavier soils better than pearl millet. Optimum growth of these plants occurs under hot, moist conditions.

Planting forage sorghums should occur after the risk of frost has past and soil temperatures are above 12°C, typically the last week of May or early June. Seeding rates range from 22–44 kg/ha (20–40 lb/acre). Generally, higher seeding rates should be used in narrow row widths and under poorer seeding conditions. Seed dealers can recommend the seeding rate for the specific variety. Planting depth should be 2–4 cm (0.75–1.5 in.). Fertilize with phosphorus and potash according to soil test. Suggested nitrogen rates for sorghums are 23 kg/t (45 lb/ton) of expected forage dry matter yield per acre. A split application of nitrogen, half at seeding and half after the first-cut, will optimize yield and quality. For weed control, see OMAFRA Publication 75, *Guide to Weed Control.*

The stage of maturity is the most important factor influencing the quality and quantity of forage produced. Typically, forage sorghums are ready for harvesting 60–65 days after planting (late July or early August) and a second cut will be ready 30–35 days later. For faster regrowth, leave at least 10 cm (4 in.) of stubble when cutting or 15–20 cm (6–8 in.) when grazing. A one-cut silage system will greatly improve yields but at the expense of feed quality. Feed quality drops dramatically after heading.

Forage sorghum and sorghum-sudan varieties with brown midrib (BMR) characteristics have been developed with significantly improved nutritional quality. BMR is a genetic mutation that reduces the amount of lignin, improving fibre digestibility, digestible energy and intake. However, there may be increased potential for less vigorous growth and lodging.

Sudangrass

Sudangrass is used for pasture. It has pencil-size stems and is palatable even after it heads out. Grazing should be delayed until the crop reaches 45 cm (18 in.). Under rotational grazing, the crop will remain productive and succulent throughout the season. Sudangrass can tolerate slightly wetter soils than the other sorghum species, but grows best on medium-to well-drained soils.

Prussic Acid Poisoning

Prussic acid (hydrogen cyanide, HCN) poisoning of livestock is a potential concern if feeding sorghums and sudangrass. Young or immature plants, plants that have been exposed to frost, and plants suffering from drought stress can contain a higher level of prussic acid. In general, sorghums are higher risk than sundangrass, and sorghum-sudangrass is intermediate. Some newer hybrid forage sorghums have been bred to have lower levels of prussic acid. Prussic acid poisoning is not a concern with millets. Silage can contain prussic acid, which can escape into the air during fermentation and when silage is moved and fed. Growth from new shoots following a frost can be high risk when pastured. To reduce the risk of prussic acid poisoning:

- Do not pasture or green chop stands less than 45–60 cm (18–24 in.) tall.
- Do not ensile or green chop sorghum over 76 cm (30 in.) tall for 3–5 days after a killing frost. Silage should be completely fermented before feeding (6–8 weeks).
- Immediately after a frost, remove the livestock from the pasture until it has dried out (usually 6–7 days). If new shoots develop, harvest the field as silage rather than pasture.
- After a drought ending rain, do not graze animals on new growth.

Nitrate Poisoning

Abnormally high nitrate (NO_3) levels in forages can result in the fatal poisoning of livestock and, if ensiled, the formation of silo gas that puts humans at severe risk. Of the various forages, sorghums, corn and cereals can accumulate the highest levels of nitrates, forage grasses accumulate intermediate levels, and legumes accumulate levels low enough to rarely be considered a problem. Nitrate poisoning is most commonly a concern when corn silage is harvested within several days of a rain that ends a severe dry period.

High nitrate levels are a potential problem under abnormal growing conditions, such as:

- very high soil levels of nitrogen (i.e., excessive rates of nitrogen fertilizer or manure or combinations of these along with legume plowdown)
- a long drought, followed by rain (in this situation, delay harvest for 10 days after rainfall, to allow conversion of nitrates to protein)
- any condition that kills the leaves, while roots and stems remain active and accumulate nitrates (such as frost, hail and sometimes drought)

Fermentation will reduce the nitrate level in the forage. Allow at least 3–5 weeks of fermentation before feeding. Suspect feeds can be tested for nitrate levels.

Note that when high nitrate forage is ensiled, deadly nitrogen dioxide gas can be produced, so precautions should always be taken. See *Silo Gas* later in this Chapter.

Forage Brassicas: Forage Rape, Kale and Stubble Turnips

Forage rape, kale and stubble turnips are excellent crops for providing high-quality pasture from September to December. See Chapter 8, *Managing for Healthy Soils*, Table 8-5, *Characteristics of cover crops grown in Ontario* or OMAFRA Publication 19, *Pasture Production*.

Table 3–3, *Characteristics of annual forage crops in Ontario*, summarizes the characteristics of annual forage crops grown in Ontario.

Table 3–3. Characteristics of annual forage crops in Ontario

Annual Crop	Use	Seeding Date	Seeding Rate	N Rate	Expected Yield Dry Matter	Harvest Maturity
Oats	haylage baleage pasture	April–August	80–100 kg/ha	30–50 kg/ha	2.5–4.5 t/ha	Late-boot to early-head
					5.5–8.5 t/ha	Heads-emerged to soft-dough
Barley	haylage baleage	April–June	100–125 kg/ha	40–70 kg/ha	2.5–5.5 t/ha	Late-boot to early-head
					5.5–9.5 t/ha	Heads-emerged to soft-dough
Oats + peas or Triticale + peas	haylage baleage	April–June	Oats or triticale: 80–100 kg/ha peas: 50–75 kg/ha	20–30 kg/ha	2.5–5.0 t/ha	Late-boot to early-head
					6.0–9.0 t/ha	Heads-emerged to soft-dough
Fall rye Winter triticale	haylage baleage pasture	August–September	90 kg/ha	55–80 kg/ha in spring	5.–9.0 t/ha	Flag-leaf or boot-stage in May
					1.0–1.5 t/ha	Graze 7 weeks after seeding or early spring
Soybeans	haylage	May–June	80–100 kg/ha	None	6.0–9.0 t/ha	Lower leaf turns yellow
Sudan grass	pasture	June 1–15	15–20 kg/ha	30–50 kg/ha	5.0–7.0 t/ha	45 cm (18 in.) in height
Sorgum-sudan hybrids	pasture haylage baleage	June 1–15	15–20 kg/ha	50–100 kg/ha	8.0–12.0 t/ha	Boot or early heading
Forage sorghums	haylage baleage pasture	June 1–15	10–30 kg/ha (multiple-cut system)	100 kg/ha	7.0–9.0 t/ha	Boot or early heading, or >1 m (3.3 ft)
Pearl millet	haylage baleage pasture hay	June 1–15	9–20 kg/ha	45-90 kg/ha	4.0–12.0 t/ha	Boot or early heading
Forage rape	pasture	July 1–15	2–6 kg/ha	45–70 kg/ha	7.0–9.0 t/ha	10–12 weeks after seeding
Kale	pasture	June–July	2–6 kg/ha	45–70 kg/ha	9.0–12.0 t/ha	10–15 weeks after seeding
Stubble turnips	pasture	July 1–15	2–6 kg/ha	80–100 kg/ha	6.0–9.0 t/ha	10–12 weeks after seeding

100 kg/ha = 90 lb/acre
1 t/ha = 0.45 ton/acre

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Table 3–3. Characteristics of annual forage crops in Ontario

Annual Crop	Use	Seeding Date	Seeding Rate	N Rate	Expected Yield Dry Matter	Harvest Maturity
Italian ryegrass	haylage baleage pasture	April–May August	39–45 kg/ha	56 kg/ha each cut	6–8.5 t/ha	8 weeks after seeding or 35–45 cm (14–18 in.) growth
Westerwold ryegrass	haylage baleage pasture hay	April–May	20–30 kg/ha	56 kg/ha each cut	8.0–12.0 t/ha	Graze or cut 6–8 weeks after seeding

100 kg/ha = 90 lb/acre
1 t/ha = 0.45 ton/acre

Establishment (Planting)

The goal of forage establishment is a uniform stand free of weeds that will grow quickly and vigorously to provide high yields. When selecting a field, consider whether it is suitable for the mixture you wish to plant. Limitations such as low pH, poor drainage or weed problems such as quackgrass, should be corrected prior to seeding. Ideally, forage seedlings should be able to emerge without a rainfall. The most critical factors to a successful seeding include a firm seedbed and proper seed placement.

Seedbed Preparation

The goal of seedbed preparation is:

- to produce a fine, firm, level seedbed that allows good control of uniform seeding depth
- to leave a well packed seedbed with good seed-to-soil contact
- to eliminate residue that may harm establishment
- to produce a smooth surface for future harvesting operations

Forage seed is very small, making good seed-to-soil contact essential for germination, particularly in dry conditions. A loose, lumpy seedbed dries out quickly, and lumps make the uniform emergence of young seedlings difficult. A firm, level, clod-free seedbed is very important for uniform seeding depth and good seed-to-soil contact. Avoid creating a soft, fluffy seedbed by deep tillage. Using a spike-tooth harrow before the drill will loosen the soil rather than pack it. Soil should be firm enough at planting for a footprint to sink no deeper than 9 mm (0.33 in.). If necessary, pack before seeding in addition to packing after the drill.

Seeding Rates and Depth

The amount of seed suggested in Table 3–2, *Forage mixtures for stored feed and pasture* and Table 3–4, *Guidelines for seeding rates for legume and pure grass stands* is intended for average to good conditions. Under excellent management and favourable conditions for establishment, these rates may be reduced by up to 25%. When coated seed is used, do not reduce these rates, because coated seed contains fewer seeds per unit weight. Do not expect very high seeding rates to compensate for poor conditions (e.g., a rough seedbed, a heavy companion crop).

Seed size can vary between varieties and between seed lots of the same variety. Seeder calibration can help avoid over- or under-seeding. For additional information see Table 3–4, *Guidelines for seeding rates for legume and pure grass stands.*

As a rule of thumb, seeding depth for most forages should be 6–12 mm (0.25–0.5 in.) on clay and loam soils, and 12–18 mm (0.5–0.75 in.) on sandy soils. Emergence declines rapidly if forage seeds are planted more than 20 mm (0.75 in.) deep. Legume seed on the soil surface may establish if moisture conditions following seeding are ideal. Success of surface seeding is much greater with late March to early April seedings (including frost seeding) than in late April or May.

Table 3–4. Guidelines for seeding rates for legume and pure grass stands

LEGEND: — = not available

Species	Seeding Rate	Number of Seeds
Legume Species		
Alfalfa	13 kg/ha (12 lb/acre)	440,000 seeds/kg (200,000 seeds/lb)
Red clover	11 kg/ha (10 lb/acre)	605,000 seeds/kg (274,000 seeds/lb)
White clover	—	1,760,000 seeds/kg (798,000 seeds/lb)
Birdsfoot trefoil	9 kg/ha (8 lb/acre)	935,000 seeds/kg (424,000 seeds/lb)
Sweet clover	8–10 kg/ha (7–9 lb/acre)	572,000 seeds/kg (259,000 seeds/lb)
Alsike	—	1,540,000 seeds/kg (699,000 seeds/lb)
Pure Grass Species[1]		
Timothy	8–10 kg/ha (7–9 lb/acre)	2,706,000 seeds/kg (1,227,000 seeds/lb)
Orchardgrass	8–10 kg/ha (7–9 lb/acre)	1,439,000 seeds/kg (653,000 seeds/lb)
Bromegrass	10–14 kg/ha (9–12.5 lb/acre)	300,000 seeds/kg (136,000 seeds/lb)
Meadow & tall fescue	9–11 kg/ha (8–10 lb/acre)	506,000 seeds/kg (230,000 seeds/lb)
Meadow fescue[2]	10–12 kg/ha (9–11 lb/acre)	506,000 seeds/kg (230,000 seeds/lb)
Perennial ryegrass	10–15 kg/ha (9–13.5 lb/acre)	500,000 seeds/kg (227,000 seeds/lb)
Reed canarygrass	10–12 kg/ha (9–13.5 lb/acre)	1,173,000 seeds/kg (532,000 seeds/lb)
Bluegrass	—	4,790,000 seeds/kg (2,173,000 seeds/lb)

[1] For early seeding on a fine, firm seedbed, these rates may be reduced by 25%, except where coated seed is being used.
[2] Use coated seed. Seed through the grain seed box.

Seeding Equipment Options

Grain Drill

The grain drill with a small (or fine) seed attachment is the most common method of seeding forages. The standard small seed box will handle legume seeds and smaller grass seeds, such as timothy and reed canarygrass, and low amounts of orchardgrass and festuloliums. Some drills have an additional large (or coarse) forage seed box with an agitator that is designed to seed larger fluffier seed, such as bromegrass and orchardgrass, that do not flow well through the standard box.

When seeding forage using most conventional grain drills, there should be a few seeds visible on the soil surface, otherwise the placement may be too deep.

Where starter phosphate fertilizer can be applied through the drill, align the drop pipes so that seed is dropped in a row over the fertilizer placed by the disc opener. Drop the seed behind the disc opener to allow some soil to cover the fertilizer band before the seed is dropped. Starter fertilizer provides an advantage mainly where soil phosphorus fertility levels are low to medium.

Packing the soil after planting results in more rapid and even germination, particularly during dry weather and on lighter soils. Press wheels help cover the forage seeds and firm the soil around the seed. Alternately, a packer can be pulled behind the drill, or packing can occur as soon as possible after seeding to prevent excessive moisture loss. Sprocket packers are preferable over smooth rollers to avoid potential crusting and to push any seed on the surface into the soil. A packer is not advised if the soil is wet, particularly on clay loam soils, where crusting can be a problem.

Air seeders or drills using a pneumatic delivery system and openers provide a capacity to seed large acreages quickly.

Packer Seeders

Packer seeders, such as Brillion seeders, can be used successfully to seed forages. They are equipped with both small (fine) and large (coarse) seed boxes, and two rollers. The first roller firms, levels and grooves the soil. The seed is then dropped on this surface. The second roller covers the seed with soil and firms it around the seed. Packer seeders do an excellent job of controlling seed depth and firming the seedbed. Packer seeders do not work as well on very hard ground or on a sandy soil. They cannot band starter fertilizer the way some drills can. This is a disadvantage mainly where soil phosphorus fertility levels are in the medium to low range.

Broadcast Seeders

Broadcast seeders main advantage is increasing the speed and capacity of seeding. Control of seeding depth is a potential problem and packing is necessary to cover the seed. Sprocket packers are preferred over smooth rollers to press surface seed into the soil.

There are two types of broadcast seeders:

1. Seeders that use spinners can give uneven distribution, particularly under windy conditions or with seed mixtures containing light and heavy seeds. This seeding method usually results in inferior stands.

2. Air-flow boom seeders overcome the problems of wind, seed segregation and spread pattern, while still permitting very rapid seeding. An alternate method mixes the forage seed with Monoammonium Phosphate (MAP) for immediate application using an air-flow fertilizer spreader.

No-Till Drills

No-till seeding of forages has been quite successful where the soil conditions following the previous crop were smooth and level. Weed control, proper seed placement utilizing depth control and use of packing wheels are all important. Where surface residue is heavy, slug damage to forage seedlings is a risk. Land susceptible to erosion will benefit from increased surface residue. However, seeding equipment must be able to handle the increased residue left by reduced tillage systems, without compromising seed placement and adequate seed-to-soil contact. When the soil is too wet, the no-till seed furrow may not close properly, resulting in poor seed-to-soil contact.

Consider these guidelines when planting into no-till or high residue conditions:

- Eliminate perennial weeds, including dandelions, quackgrass, and winter annuals before seeding. Control broadleaf annual weeds in new seedings with a herbicide application.
- Ensure residue from the previous crop is evenly distributed. Manage any excessive residue from the previous crop to improve seed placement and to prevent slug damage. No-till spring seedings into soybean, cereal and corn silage stubble provide the most reliable results.
- Seeding depth should be 6–12 mm (0.25–0.5 in.) on clay and loam soils, and 12–18 mm (0.5–0.75 in.) on sandy soils. Check that openers are placing seed into the soil, rather than into surface residue.

Direct Seeding or Seeding With a Companion Crop

Companion crops are sometimes also referred to as “nurse crops”. Forage seeding under a companion cereal crop (oats, triticale, barley) can suppress annual grass weeds and provide rapid protection from erosion on rolling land. The disadvantage of a companion crop is that it competes with the forages for moisture, light and fertility. If any of these items are deficient, the forage seeding will suffer before the grain crop does.

Seeding forages without a companion crop removes this potential threat to establishment. Direct-seeded forage stands are often thicker and more uniform, particularly with alfalfa birdsfoot trefoil and reed canarygrass, which do not tolerate heavy shading. Since a cereal forage crop is not competing for soil moisture, direct seedings are less affected by June or July dry periods.

Early spring direct seedings can be expected to provide 1–2 cuts of forage in the seeding year, yielding 50%–65% of an established stand. Under ideal conditions, first-cut can be harvested 60–70 days after seeding.

Direct seedings are more common in Ontario, where:

- fields have a lower risk of soil erosion
- good drainage allows early spring seeding
- rotational weed control is good
- uniformly high nutrient quality haylage is required such as dairy farms

Direct seedings are not successful on all farms. Weed competition can be a greater problem with direct seeding than with underseeding a companion crop. A cereal companion crop can provide some early protection to fields that have a greater risk of water erosion during the initial establishment period, including lighter soils types with slope. Direct seedings on heavier clay loam soils can require more skillful seedbed preparation and seeding, where they, are more vulnerable to crusting and seedling emergence problems if heavy rains follow seeding.

Harvesting the Companion Crop as Silage

Harvesting the companion cereal crop by combining it as grain is not a preferred practice because it reduces the establishment of the forage crop for the life of the stand. Harvesting the cereal crop at the boot-stage as haylage or baleage reduces the competition, enabling better forage establishment while still providing weed suppression and erosion control, and providing additional forage. The companion crop is removed before it lodges or competes excessively for light and moisture. If the cereal crop is cut and lays in the swath for an extended period while wilting, it has the potential to damage the new forage seeding.

Although some producers use a full cereal seeding rate and apply nitrogen to maximize forage yield, the heavier growth can increase the risk of a less successful forage establishment. Seeding at reduced rates (50%) and avoiding N application usually improves the forage establishment.

Oats are typically the preferred forage cereal. Although rust is a potential concern, forage oats tend to out-yield barley (especially in poorer conditions and later seedings), with less cereal regrowth and heading in the second-cut, and without the awns. Peas are sometimes added to the cereals to improve forage nutrient quality. This eliminates having the option of herbicide weed control and can increase the risk of extended wilting that may damage the forage seeding.

Match the stage of cereal at cutting to the livestock nutritional requirements. For high feed quality, cereals should be harvested at the boot stage. Delaying harvest to the fully headed stage will increase yield but reduce forage quality. Cereals can reach the boot stage in as little as 60 days, so if seeded before the first week of May they could be harvested in late June or early July. With reasonable soil moisture following harvest, it is quite possible to obtain another cut of forage during August in areas with 2,800 crop heat units or more.

More information about forage production from spring cereals can be found at fieldcropnews.com.

Harvesting the Companion Crop as Grain

Harvesting cereal grain that has been underseeded to forage increases the risk of a less successful forage stand. Although it provides a grain crop and straw while the forage crop is being established, competition from the cereal reduces forage establishment and subsequent yields. Lodging of the cereal crop or delayed baling of straw are also significant risks. The primary purpose of the seeding is to establish the forage, while grain and straw production are of secondary importance. Where grain is harvested from a companion crop, the following considerations will help to reduce the potential damage to the new forage seeding:

- Spring wheat and spring triticale generally provide less competition to the forage seeding than oats or barley. Six-row barley is preferable to two-row barley.
- As a general rule, select the strongest-strawed, shortest and earliest grain variety in any species for the least competition.
- Reduce the spring grain seeding rate to 60–70 kg/ha (54–62 lb/acre).
- Reduce the nitrogen fertilizer (<15 kg N/ha or 13 lb/acre) or manure rate to minimize the risk of a dense grain crop and of lodging.

Seeding Time

Spring Seeding

The most reliable time to seed forages is early spring, regardless of whether the crop is direct-seeded or seeded with a companion crop. With a spring seeding, moisture is usually adequate, and the plants are well established for winter survival. Plant as early as a favourable seedbed can be prepared to increase the chances of adequate moisture during the critical germination and early growth period.

Summer Seeding

Summer seeding can be a viable alternative to spring seeding. It has the advantage of providing a full yield the following year. A summer seeding can typically follow winter or spring cereal harvest. Companion crops are not recommended in summer seedings because they compete too strongly for available soil moisture.

Seeding Date

Seeding too early in the summer increases the risk of hot, dry conditions, affecting germination and seedling development. Seeding too late increases the chance of receiving a killing frost before legume seedlings are adequately established to accumulate enough root reserves to survive the winter. Legumes seeded after early September rarely survive the winter, since small legume plants are more susceptible to heaving. Even if these plants survive, they will be slower starting and lower yielding. Alfalfa requires approximately 6 weeks of growth after germination to survive the winter, and will generally survive if the crown develops before a killing frost.

Summer-seed alfalfa mixtures before the following dates:

- more than 3,100 CHUs — August 10–20
- 2,700 to 3,100 CHUs — August 1–10
- less than 2,700 CHUs — July 20–30

Birdsfoot trefoil has slow seedling development, so summer seedings are usually unsuccessful. Grasses can tolerate later seedings. September seeding of straight grasses may be successful, with the exception of reed canarygrass, which is slow to establish.

Seedbed Preparation

Seed-to-soil contact is particularly important in dry summer conditions. A loose, lumpy seedbed dries out quickly. Packing can help preserve moisture. A fine seedbed can be more difficult to prepare in August on clay loam soils, compared to loams, sandy loams and silt loams. Avoid summer seeding on heavier soils that have a history of alfalfa heaving.

Weed Control and Volunteer Grain

Winter annual weeds can be a common problem in summer seedings, and herbicide application may be required. Refer to OMAFRA Publication 75, *Guide to Weed Control*. Be cautious not to delay growth due to a herbicide effect.

Volunteer grain can be a serious problem in summer seedings following cereals, especially winter wheat, because it may be thick and competitive. Oats or barley will winterkill in November, but winter wheat will be present until the first cut the following year. Tillage and glyphosate can be used to reduce the problem of volunteer cereals, but delay seeding.

No-Till

No-till summer seeding can be successful if proper attention is paid to residue management, seed placement and weed control. However, using no-till to reseed an existing alfalfa field in August is not recommended due to alfalfa autotoxicity, slugs and disease that may exist in the old sod.

Alfalfa Autotoxicity

Seeding alfalfa after alfalfa is high risk because old stands of alfalfa release a toxin that reduces germination, root development and growth of new alfalfa seedlings. This is called autotoxicity. Roots are swollen, curled, discoloured and lack root hairs. The negative effects on root growth can significantly impact yields for the life of the stand.

Reseeding alfalfa within 2–3 weeks of killing an old alfalfa stand will result in reduced germination and thin stands. A longer delay will allow full stand establishment, but because the toxins are present for up to 6 months, the plants can permanently suffer damage below ground that will limit yields for the life of the stand. For maximum yields, if the alfalfa is 2 or more years old, an intervening year of an alternate crop is required before reseeding to alfalfa.

The toxins from established alfalfa are not present the first year in new seedings, so seeding failures or new plants that were winterkilled can be reseeded without an autotoxicity effect. This would include a summer seeding into an unsuccessful spring seeding, or a seeding in the spring following an unsuccessful summer seeding or previous spring seeding.

It is not recommended that interseeding be done to thicken an established alfalfa stand, as this is rarely successful. New seedlings often germinate, look acceptable early and then die out over the summer. In emergency situations, thin spots can be interseeded with red clover instead.

Frost Seeding Pastures

Broadcast-seeding legumes (clovers and trefoil) into established pastures in late winter or early spring can be an effective way of increasing the legume content in a pasture stand. Broadcast the seed when the ground is still frozen. The freeze thaw action of early spring will help the seeds establish good soil contact. Pastures should be aggressively grazed the previous fall to reduce the competition from the established perennial species in the pasture. Alfalfa and most grass species generally have low to very low success rates when frost seeded.

Inoculation

For normal growth, all legumes must have nitrogen-producing nodules on their root systems. These nodules are produced by rhizobium bacteria.

Legume species (alfalfa, clover, birdsfoot trefoil) require their own specific strain of rhizobia *Rhizobium* for proper nodulation. If a legume is being planted for the first time in a field, the seed must be inoculated with the proper strain of rhizobium bacteria before planting. Pre-inoculated seed is satisfactory, provided that the inoculant is applied in the current season. Since the inoculant must be alive, note the expiry date and handling precautions on the packet to ensure effective nitrogen fixation. When a forage legume species has routinely been grown in a field as part of the rotation, these bacteria are usually present in the soil and should result in good nodulation. The cost of the rhizobia is low in comparison to the cost of seed. If there is any doubt about the presence of rhizobia in the soil, the seed should be inoculated.

Fertility Management

Nitrogen

Forage stands that are less than 50% legume have a yield response to nitrogen (N) fertilizers. For nitrogen guidelines, see Table 3–5, *General nitrogen guidelines — perennial forages*.

Grass stands containing less than one-third legumes require nitrogen to optimize yield. Where conditions permit, it is generally more economical to grow mixtures containing legumes. It can be profitable to fertilize grass stands consisting of productive forage grass species. Improved grass stands that are well managed will respond well to additional nitrogen. Suggested nitrogen rates for grass stands (less than one-third legume) are 23 kg/t (45 lb/ton) of expected forage dry matter yield.

The use of nitrogen also increases the protein level in the grass. Make the first application for hay or pasture as early as possible in the spring at green-up, followed by a second application after the first cut and a third application after the second cut. To avoid the danger of nitrate toxicity, apply no more than 170 kg/ha (150 lb/acre) of nitrogen at any one time.

Nitrogen deficiency in forages shows up as a general yellowing and stunting of the plants. It may appear in the lower parts of the plants first. In legumes, a nitrogen deficiency usually indicates poor nodulation and/or low soil pH.

Table 3–5. General nitrogen guidelines — perennial forages

Crops	Suggested Nitrogen
Legume or legume-grass at seeding	
without a nurse crop	0 kg/ha
with a nurse crop	15 kg/ha
unimproved pasture	50 kg/ha
grass for seed	90 kg/ha
Hay or pasture	
half or more legumes	0
one-third to one-half legumes	60 kg/ha
grass (less than one-third legumes)	23 kg/t (45 lb/ton) of expected dry matter yield
100 kg/ha = 90 lb/acre	

Phosphate and Potash

Phosphate (P_2O_5) and potash (K_2O) guidelines are given in Table 3–6, *Phosphate (P_2O_5) guidelines for forages* and Table 3–7, *Potash (K_2O) guidelines for forages*. These guidelines are based on OMAFRA-accredited soil tests using the sufficiency approach which applies the most economic rate of nutrients for a given crop year. For information on the use of these tables or if an OMAFRA-accredited soil test is unavailable, see Chapter 9, *Soil Fertility and Nutrient Use, Fertilizer Guidelines*.

When direct-seeding on soils that require phosphate fertilizer, establishment may be improved by the placement of a high phosphate fertilizer 5 cm (2 in.) directly below the seed. Using a grain drill with fertilizer and grass seed attachments, this placement may be accomplished by drilling the fertilizer through the furrow opener and dropping the forage seed on a firm soil surface directly behind the furrow opener. Usually it is advisable to firm the soil surface immediately after seeding.

Potash may be more effective in promoting persistence if it is applied within the 6 weeks before the start of the fall rest period. Potash deficiency is visible in alfalfa with symptoms of small, light dots on the leaflets. These dots can be on any part of the leaflet but are usually concentrated near the margins (Photo 3–1). Potash deficiency symptoms in grasses and clovers are less distinctive, but result in overall slow growth and poor yield. However, high soil-potassium levels can result in luxury consumption of potassium by alfalfa and subsequent nutritional problems when fed to dairy cows prior to calving. Potassium applications on soils testing over 150 ppm will not significantly increase winter hardiness and are not recommended.

Photo 3–1. Potash deficiency symptoms in grasses and clovers are less distinctive, but result in overall slow growth and poor yield.

Phosphate, if required, may be applied with the potash or at other times of the year. Phosphate deficiency symptoms are rare and non-specific in forages, but a shortage of phosphate may manifest itself as stunting and poor winter survival of legumes.

Table 3–6. Phosphate (P_2O_5) guidelines for forages

Based on OMAFRA-accredited soil tests.

Profitable response to applied nutrients occurs when the increase in crop value, from increased yield or quality, is greater than the cost of the applied nutrient.

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (Chapter 9, Manure section).

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

Sodium Bicarbonate Phosphorus Soil Test	At Seeding With or Without a Nurse Crop	Band Seeded Without a Nurse Crop[1]	Established Stands	Unimproved Pasture
0–3 ppm	130 kg/ha (HR)	130 kg/ha (HR)	180 kg/ha (HR)	70 kg/ha (HR)
4–5 ppm	110 kg/ha (HR)	110 kg/ha (HR)	120 kg/ha (HR)	60 kg/ha (HR)
6–7 ppm	90 kg/ha (HR)	90 kg/ha (HR)	90 kg/ha (HR)	50 kg/ha (HR)
8–9 ppm	70 kg/ha (HR)	70 kg/ha (HR)	60 kg/ha (HR)	30 kg/ha (HR)
10–12 ppm	50 kg/ha (MR)	50 kg/ha (MR)	30 kg/ha (MR)	20 kg/ha (MR)
13–15 ppm	30 kg/ha (MR)	40 kg/ha (MR)	20 kg/ha (MR)	20 kg/ha (MR)
16–20 ppm	20 kg/ha (MR)	30 kg/ha (MR)	0 (LR)	0 (LR)
21–25 ppm	20 kg/ha (MR)	20 kg/ha (MR)	0 (LR)	0 (LR)
26–30 ppm	0 (LR)	20 kg/ha (LR)	0 (RR)	0 (LR)
31–40 ppm	0 (LR)	20 kg/ha (LR)	0 (RR)	0 (RR)
41–50 ppm	0 (RR)	20 kg/ha (LR)	0 (RR)	0 (RR)
51–60 ppm	0 (RR)	0 (RR)	0 (RR)	0 (RR)
61 ppm +	0 (NR)[2]	0 (NR)[2]	0 (NR)[2]	0 (NR)[2]

100 kg/ha = 90 lb/acre

[1] For use only where seed is banded directly above the drilled fertilizer.
[2] When the response rating for a nutrient is “NR,” application of phosphorus in fertilizer or manure may reduce forage yield or quality and may increase the risk of magnesium deficiency.

Table 3–7. Potash (K_2O) guidelines for forages

Based on OMAFRA-accredited soil tests.

Profitable response to applied nutrients occurs when the increase in crop value, from increased yield or quality, is greater than the cost of the applied nutrient.

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (Chapter 9, Manure section).

LEGEND: HR = high response MR = medium response LR = low response RR = rare response NR = no response

Ammonium Acetate Potassium Soil Test	At Seeding With or Without a Nurse Crop	Summer or Fall Applications New Seedings and Established Stands
0–15 ppm	90 kg/ha (HR)	480 kg/ha (HR)
16–30 ppm	80 kg/ha (HR)	400 kg/ha (HR)
31–45 ppm	70 kg/ha (HR)	320 kg/ha (HR)
46–60 ppm	50 kg/ha (HR)	270 kg/ha (HR)
61–80 ppm	40 kg/ha (HR)	200 kg/ha (HR)
81–100 ppm	30 kg/ha (MR)	130 kg/ha (HR)
101–120 ppm	20 kg/ha (MR)	70 kg/ha (MR)
121–150 ppm	20 kg/ha (MR)	20 kg/ha (MR)
151–180 ppm	0 (LR)	0 (LR)
180–250 ppm	0 (RR)	0 (RR)
251 ppm +	0 (NR)[1]	0 (NR)[1]

100 kg/ha = 90 lb/acre

[1] When the response rating for a nutrient is "NR," application of potash in fertilizer or manure may reduce forage yield or quality and could increase the risk of milk fever in dry dairy cows. For example, potash application on soils low in magnesium may induce magnesium deficiency.

Sulphur

Sulphur (S) deficiency is being observed more frequently on alfalfa in Ontario with significant reductions in yield. The appearance of sulphur deficiency is similar to nitrogen deficiency with general yellowing of the plants. Sulphur availability varies from year to year according to temperature and rainfall. Sulphur is similar to nitrate and can be leached below the root zone. Sulphur in manure is in elemental, or a more slowly available form of S. Sulphur deficiencies are more likely to occur in northwestern Ontario, on low organic matter soils, and soils that have not had a manure application for several years. Tissue sampling of alfalfa is a diagnostic tool used to predict whether there will be a response to applying S, see Table 3–8, *Interpretation of plant analysis for alfalfa*. If required, apply 5 lb/acre of S/ton of expected dry matter yield. Sulphur must be in the sulphate form to be utilized by plants, so application of sulphate-S provides a more immediate yield response. Applying elemental-S bulk, blended with other fertilizer, is a cost-effective long-term method of providing S.

Micronutrients

Boron

Boron (B) is important for alfalfa, but application is not required on all soils. A deficiency shows up mainly on high-pH, sandy soils. Boron applications are often advised on sandy soils and, in particular, the sandy loam and loam soils in the area east of the Niagara Escarpment up to and including Frontenac County. Boron deficiency is seen most frequently on droughty soils under dry conditions.

As boron deficiency becomes more visual, the youngest upper leaves of the plant become yellow to red in different plants (Photo 3–2). Growth can be severely stunted and winter hardiness reduced.

Boron deficiency can usually be corrected or prevented by an application of 1.0–2.0 kg/ha (0.9–1.8 lb/acre) of boron broadcast with the other fertilizer (e.g., potash). Boron should not be banded at seeding.

Photo 3–2. As boron deficiency becomes more visual, the youngest upper leaves of the plant become yellow to red in different plants.

Table 3–8. Interpretation of plant analysis for alfalfa

Values apply to the plant cut at normal mowing height at the late bud stage.

LEGEND: — = no data available

Nutrient	Critical Concentration[1]	Maximum Normal Concentration[2]
Nitrogen (N)	—	5.5%
Phosphorus (P)	0.20%	0.5%
Potassium (K)	1.70%	3.5%
Calcium (Ca)	—	4.0%
Magnesium (Mg)	0.20%	1.0%
Sulphur (S)	0.22%	—
Boron (B)	20.0 ppm	90.0 ppm
Copper (Cu)	5.0 ppm	30.0 ppm
Manganese (Mn)	20.0 ppm	100.0 ppm
Molybdenum (Mo)	0.5 ppm	5.0 ppm
Zinc (Zn)	10.0 ppm	70.0 ppm

[1] Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" concentration.
[2] Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.

Other Micronutrients

Deficiencies of copper, zinc or manganese have not been observed in forages in Ontario.

Plant Analysis

While analyzing forage legumes, sample each species separately. Cut the plant at normal mowing height at the late bud stage, see Table 3–8, *Interpretation of plant analysis for alfalfa*. Plants suspected of nutrient deficiency, however, should be sampled as soon as the problem appears. For sampling at times other than heading, and for species other than alfalfa, samples should be taken from both deficient and healthy areas of the field for comparative purposes. A soil sample should be taken from the same area and at the same time as the plant sample.

Manure on Forages

Liquid manure applied to forage crops provides significant nutrients N-P-K-S and micronutrients. It also provides a seasonal convenience for application and can improve forage yields and quality. Manure application to grass or older grass-alfalfa stands provide the largest benefit. A few key considerations include:

- Apply uniformly, as soon after harvest as possible, and before regrowth. Tire traffic over new growth will reduce yields. If soil conditions are wet, delay application until after the next cut.
- Ideal application rates of liquid dairy manure (between 33–45 m^3/ha or 3,000–4,000 gal/acre) provide approximately 56–50–100 kg/ha (50–45–90 lb/acre) of available N-P205-K20.
- Application of liquid manures that supply more than 85 kg/ha (75 lb/acre) as ammonium N should be avoided on sunny, hot days to prevent burn to new tissue.
- Average dairy manure (8% dry matter) nitrogen composition is about 50% ammonia and 50% organic nitrogen. Ammonia increases as dry matter decreases and ammonia loss can be as high as two-thirds of the ammonia portion of the manure nitrogen. It is highest during the 24 hours after application and in areas where higher rates have "pooled". Rainfall after application reduces ammonia loss.
- Unless solid manure is of a consistency that allows uniform thin application (no large clumps), there is the potential for smothering. Moving solid bed-pack manure from the barn to temporary field storage in early spring helps improve manure composition for more uniform spreading.
- Avoid applying manure to fields where forage will be made into baleage because high levels of butyric acid can result. This is not an issue with haylage.
- Feeding dry hay from a forage stand where manure was applied can potentially spread Johne's disease. Avoid manure application to stands where forage will be fed to young cattle (<1 year of age) in the same

growing season. Ensiling forages may reduce the risk of spreading Johne's disease.
- Sample the manure applied to forages and send for analysis so that nutrients applied can be credited.

Liming

Legumes generally are not tolerant of acid soil conditions. Alfalfa yields are very limited on low pH soils, partially due to poor nodulation. Lime fields to a pH of at least 6.7. Alfalfa yields drop dramatically below this level. Lime reacts slowly with acid soils, so they should be limed and incorporated 1 year before seeding at rates indicated by soil tests, see Chapter 9, *Soil Fertility and Nutrient Use, Soil Acidity and Liming.* Applying lime to established stands is not effective.

Harvest and Storage

Pasture Management

A well-managed pasture will provide an abundance of low-cost forage for livestock. The key to good pasture production is rest and recovery time for the pasture after each grazing. To harvest the optimum amount of forage and achieve the best livestock performance, use a multi-paddock rotational system. Ideally, a pasture will contain at least 35% legume in the forage being consumed by the livestock. Soil drainage and texture will influence the choice of forage species. Pastures with less than 35% legume content will benefit from the application of nitrogen at 50–75 kg/ha (45–67 lb/acre). Timing should coincide with good growing conditions and the need for more pasture. Use multiple applications if applying a higher rate.

Rotational Grazing

Spring turn-out of livestock should be timed according to the grass growth. Promptly graze early species, such as orchard grass, or growth will become too mature. Rotate the grazing fairly quickly. The faster the grass is growing, the quicker the rotation should be. With rotational grazing, it is important to gauge moving the livestock based on the last paddock planned for grazing in the rotation. In the early part of the growing season, a complete rotation may take 20 days. Late in the season, it may take 40 or more days for adequate re-growth and recovery before re-entry into a paddock.

Bloat Management on Pasture

Legumes can cause bloat of ruminant livestock. The younger the plant, the greater the risk to livestock. When grazing pasture with greater than 50% legume, there are a number of steps that will reduce the risk of bloat:

- Ensure the livestock have been well fed before they enter the pasture.
- Move livestock when the pasture is dry, not early in the morning with heavy dew or when wet with rain.
- Offer dry stemmy hay to assist rumen stimulation.
- Graze legumes when they're in bloom.
- Consider using an anti-bloat feed additive, such as poloxalene.
- Offer small areas at a time (equivalent to 1 day) to encourage the livestock to eat the stems as well as the bloat-causing leaves.

For more information on pasture management see OMAFRA Publication 19, *Pasture Production,* available on the website at ontario.ca/crops.

Forage Quality

The type of livestock being fed determines the appropriate quality of forage harvested for storage. Match forage quality to the nutritional requirements of the animal. High-producing dairy cattle require quality feed that is high in digestible energy and protein. The benchmark alfalfa analysis for high-producing dairy cows is 20% crude protein (CP), 30% acid detergent fibre (ADF) and 40% neutral detergent fibre (NDF). High fibre digestibility (NDFd) is also required. For a beef cow, the most appropriate hay is more mature and higher yielding, and is therefore lower in protein and digestibility. Many horses have much lower nutritional requirements, so owners prefer hay that is more mature and contains more grass than is common in dairy hay. Horses are sensitive to respiratory and colic issues, so it is very important that horse hay be free of rain-damage, mould and dust. The premium hay market also requires hay to be green in appearance and entirely free of weeds. The remainder of this section will use the term "high nutrient quality" to mean high in protein and digestible energy.

Laboratory analyses of forages are essential for accurate ration formulation. The nutrient content of forages varies greatly depending on the type, stage of maturity at cutting and how well it is preserved.

OMAFRA Factsheet, *Definition of Feed Manufacturing and Livestock Nutrition Terms,* provides additional guidance with interpreting forage analysis reports. See ontario.ca/crops for more information.

Measuring Corn Silage Digestible Energy

Corn silage is unique since it consists of two very different components — high moisture grain and stover. High digestible energy is important to reduce the need for supplemental grain. Lower neutral detergent fibre (NDF) and increased fibre digestibility (NDFd) are important for increasing intake, as well as energy.

Digestible energy of corn silage is primarily determined by the relative amounts of starch and fibre (NDF) and their digestibility. In the past, acid detergent fibre (ADF) was used to estimate energy, and NDF was used to estimate intake, but these measures alone do not consider digestibility. Newer methods more accurately estimate corn silage digestible energy using crude protein (CP), NDF, NDFd, starch, ash and fat. Starch digestibility can also be estimated using moisture, kernel processing scores and other laboratory starch digestibility tests.

Forage Harvest Timing

The timing of harvest is the most important consideration when trying to produce high nutrient quality forage. Forage crops decline in feeding value as they mature. Once alfalfa buds appear, feeding value declines about 0.2% per day in protein and about 0.4% per day in digestibility, see Table 3–9, *Digestibility and protein of alfalfa and bromegrass at various stages of maturity*. There are some varietal differences in maturity in alfalfa and grasses, which provide an opportunity to stagger them for appropriate harvest. Short delays in cutting result in significantly lower forage nutrient quality. Finding a window of dry weather can complicate things even further.

The timing of cutting is determined by the nutritional requirements of the livestock being fed. Cutting alfalfa at the pre-bud or early-bud stage will result in reduced yields and may weaken the stand. Extremely low fibre levels may result in nutritional problems. With grasses, a compromise between yield and quality typically occurs at the "boot stage." There are varietal differences in maturity within the forage grass species. Early orchardgrass varieties begin to head the earliest, usually followed by reed canarygrass, tall fescue, smooth bromegrass, and then timothy. Late maturing orchardgrass varieties head 2–3 weeks later than earlier varieties. Delayed harvesting of forages will give higher yields and greater plant persistence, but lower feed quality. With a large acreage of forage, it is advisable to start cutting earlier to ensure the later-cut material will still have adequate quality.

Subsequent second and third cuttings of alfalfa may be at intervals of approximately 30 days (mid-bud) to 40 days (early flower) or more, depending on whether the goal is high quality or maximum persistence and yield, see *Forage Winterkill*.

Predicting Alfalfa Quality in a Standing Crop

Methods being used to determine when to begin cutting first-cut alfalfa include:

- the calendar date
- stage of development (mid-bud, full-bud, etc.)
- plant height
- growing degree days (GDD), see Chapter 10, *Field Scouting, Growing Degree Days*
- Predictive Equations for Alfalfa Quality (PEAQ) stage of development and height
- scissors-cut
- laboratory analysis

Table 3–9. Digestibility and protein of alfalfa and bromegrass at various stages of maturity

		% Digestibility		% Crude Protein	
Stage of Maturity	**Date**	**Alfalfa**	**Bromegrass**	**Alfalfa**	**Bromegrass**
medium bud	June 4	72.6	73.8	21.5	13.4
early flower (heads emerged)	June 20	65.2	67.2	17.0	10.0
full flower	June 30	62.1	60.6	16.2	6.7
early seed	July 6	60.9	59.7	15.6	5.8

Many dairy producers base cutting decisions using NDF as the primary quality variable. For high-producing dairy cows, optimum alfalfa NDF for intake and dietary fibre is approximately 40%. With warm weather, NDF can increase about 0.7 units per day, and therefore nutrient quality can drop rapidly. Harvesting too early reduces yield, limits dietary fibre with excessive soluble crude protein. NDF can vary from one year to the next by up to 10% when cutting is on the same calendar date. The relationship between morphological stage, such as early- or late-bud stage, and NDF can also be quite variable. The PEAQ method combines stage of development and stem height to estimate the NDF of the alfalfa in a standing crop. A PEAQ stick incorporates the NDF estimates onto an easy-to-read measuring stick, which can be used in the field as a tool in making cutting decisions. For details on how to use the PEAQ system, see *Predicting Alfalfa Quality Using PEAQ* on the OMAFRA website at ontario.ca/crops. The most accurate method to monitor forage quality in a standing crop, especially mixed alfalfa-grass stands, is the scissor-cut analysis with a rapid turnaround time offered by some laboratories.

Forage Harvesting Methods

The greatest amount of feed value is stored when both field and storage losses are minimized. Storing dry hay results in high field losses but relatively small storage losses. On the other hand, storing forages as haylage gives lower field losses but higher fermentation and storage losses see Figure 3–2, *Estimated hay and haylage harvest and storage losses.* Haylage and baleage have the advantage of requiring a much shorter period of suitably dry weather without rain. Dry hay has the advantage that it can be easily transported and marketed, while chopped haylage must be fed close to where it is stored. Large bale haylage, or "baleage" has the advantage that it can be harvested and fed with already existing hay equipment, with the addition of the wrapper. Baleage also comes with its own storage. The trend is towards more haylage and baleage. With large forage acreages, it is important for a producer to have sufficient equipment capacity to cut, rake, bale or chop a large quantity of forage when the weather windows of opportunity present themselves.

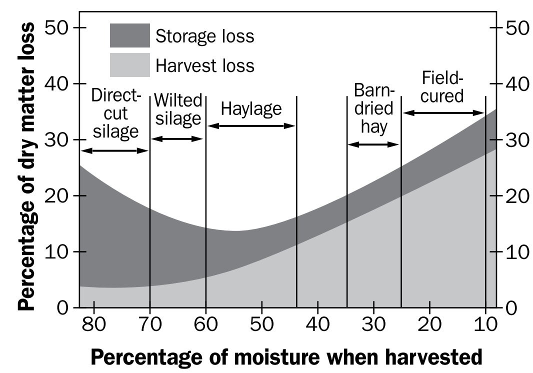

Figure 3–2. Estimated hay and haylage harvest and storage losses.

Adapted from Hoglund, 1964

Fast wilting and drying is a key to successful hay and haylage making. This minimizes respiration losses of sugars and reduces the risk of rain-damage. In Ontario, good haymaking periods without rain can be very narrow. There is a constant challenge between getting the hay dry enough to bale before the next rain, or baling before the hay is quite dry enough and getting mouldy, dusty hay. Losses from conditioning and raking (excessive leaf loss) have to be balanced against baling at too high a moisture or potential rain-damage.

Cutting and Conditioning

Disc mowers perform more dependably than sickle mowers in situations where forage is lodged, or in very thick grass stands. Disc mowers also can operate at higher speeds and capacity, are easier to repair in the field, but are usually more expensive.

Hay conditioners crush, crimp or flail the plant stems and speed up drying. Faster drying reduces the risk of hay being rained on and synchronizes the drying of leaves and stems, which can reduce leaf shatter. Grasses generally dry faster than legumes. Conditioners should be maintained and adjusted to ensure the optimal amount of conditioning. Refer to the operator's manual.

Swaths should be left as wide as feasible after cutting in order to speed drying time and minimize respiration losses of sugars. A wide swath decreases forage density and windrow humidity and increases the evaporative surface exposed to sunshine. Many mower-conditioners can be adjusted to widen the swath, or fins can be used. A common alternate approach is to use a tedder after cutting to spread the swath to the full width of the mower.

Photo 3–3. Swaths should be left as wide as feasible after cutting to speed drying and reduce respiration losses of sugars.

Dry Hay

Harvest Losses

There are a number of losses associated with the production of dry hay. Since the leaves contain about half of the dry matter and two-thirds of the protein, leaf loss has significant impacts on yield and quality.

Respiration

Even after cutting, forages continue to respire and consume sugars until the moisture content drops sufficiently. Under relatively fast drying conditions, these losses can be kept to a minimum: 2%–8% of total dry matter (Photo 3–3). Under extended drying conditions (low temperature, high humidity, etc.), the plants take longer to dry down, and dry matter losses as high as 16% have been measured.

Weathering

Rainfall on cut hay causes respiration and other significant losses. Nutrients such as soluble sugars are leached from the leaves, leaf loss increases, and microbial growth begins. Rain-damage can be more costly than what a laboratory analysis might indicate. Highly digestible sugars are lost, and both digestible energy and protein can be reduced. Weathering also decreases palatability and the amount of hay the animals will eat. Rain damage increases the amount of mould on hay in the swath, which can make it less palatable and unsuitable for the horse market.

Mechanical Losses

As forages cure, the leaves and small stems become more brittle. Any mechanical operation, such as raking or tedding, done on material having less than 40% moisture causes leaf losses. Leaf losses increase as moisture content declines. If possible, rake when hay is moist. Leaf loss can be reduced by raking lower-moisture hay in the morning while dew is still present, slowing the speed of rotary rakes and turning a windrow with an invertor or merger. Tedders are more commonly used on grassier hay crops and can result in significant alfalfa leaf loss at lower moistures. Losses at the baler pick-up and in the baling chamber can be reduced by raking light windrows together at higher moisture and by traveling at maximum ground speed.

Potential Hay Harvesting Losses

The losses from haymaking that have been reported in research trials are summarized in Table 3–10, *Potential haymaking losses*.

Table 3–10. Potential haymaking losses

Source of Loss	Loss of Dry Matter
Respiration	2%–16%
Cutting and conditioning	2%–5%
Raking	5%–25%
Baling small bales	3%–8%
Baling large bales	1%–15%
Transportation	1%–10%
Potential total loss	10%–71%

Raking and Swath Manipulation

Rotary rakes are considered the best to speed drying, leaving a uniform, fluffy swath. Originally designed to rake grasses, they can result in higher alfalfa leaf loss if not used properly. Rakes should be adjusted to minimize rotational speed relative to ground speed. Height off the ground should be properly adjusted so that the tines do not incorporate soil into the windrow, resulting in high ash, dusty hay. Wheel rakes can "rope" the windrow and do not leave the swath as fluffy, uniform, and open as a rotary rake, and can leave bunches that are slower to dry. Large wheel rakes have high capacity and are useful at bringing together multiple swaths into a single windrow in lower yielding fields, or for chopping in a haylage program.

Tedders are similar to rotary rakes in design, but widen the swath rather than narrowing it into a windrow. They are often used soon after cutting to widen the swath to full width without driving on it for faster drying. At lower moistures (<50%) they are better suited for grasses than alfalfa, where they may cause significant leaf loss.

Reconditioners are also sometimes used to add conditioning and to manipulate the swath to speed drying. With hay that is almost, but not quite ready to bale, it can often be difficult to get the bottom of the swath to dry. To prevent leaf loss by raking this low moisture forage, a windrow inverter or merger can be used to more gently turn the swath upside down for exposure to the sun and drying.

Storage Losses

Hay that is sufficiently dry and is stored off the ground and under cover will normally experience minimal storage losses. Hay baled before it is sufficiently dry is at risk of significant spoilage due to the growth of mould and bacteria. This microbial growth and respiration metabolizes sugars in the hay and producing heat and more moisture. This results in poor quality, mouldy, dusty, less digestible, and less palatable hay. Heating also results in the risk of spontaneous combustion. The amount of potential damage to the hay is related to:

- percentage of moisture in the hay
- density of the bale and how tightly bales are packed in storage
- storage ventilation
- temperature and humidity of the outside air

Dry hay storage moistures guidelines for various bale types are outlined in Table 3–11, *Storage moisture guidelines and approximate bale weights*.

Managing hay in storage to ensure continued dry down is very important. When hay is baled and placed into storage, moisture begins to migrate from the high humidity conditions inside the bale to the outside, in what many refer to as "sweating" or curing. Allow moisture to dissipate as quickly as possible by ensuring good storage ventilation. This can be done by placing bales on skids or pallets and providing some spacing between rows of bales. A small amount of plant metabolism initially continues, producing some heat and moisture. It is not unusual to see the moisture in newly baled hay creep up a small amount and hay temperatures increase up to 5°C from the ambient temperature when it was baled. Eventually temperatures and moistures should begin to decline. If moistures and temperatures continue to climb, there is significant microbial growth occurring. Use a hay moisture and temperature probe to monitor for potential heating.

Hay Heating and Spontaneous Combustion

Spontaneous heating and combustion occur when sufficient moisture, oxygen and organic matter are present together to support the growth of bacteria and moulds. The reaction can be self-sustaining and can ignite if high enough temperatures are reached. Spontaneous combustion of hay usually occurs within the first 2 months of storage.

Table 3–11. Storage moisture guidelines and approximate bale weights

Bale Type	Bale Size	Storage Moisture	Approximate Bale Weights (as fed)[1]
Small square bales	~0.9 m x 0.38 m x 0.45 m (~3 ft x 1.25 ft x 1.5 ft)	15%–18%	22–35 kg (50–75 lb)
Large round bales – soft core	1.2 m x 1.5 m (4 ft x 5ft)	13%–16%	180–275 kg (400–600 lb)
Large round-bales – hard core	1.2 m x 1.5 m (4 ft x 5 ft)	12%–15%	385–408 kg (~850–900 lb)
Large round-bales – hard core	1.5 m x 1.8 m (5 ft x 6 ft)	12%–15%	690–910 kg (~1,500–2,000 lb)
Large square bales	0.9 m x 0.9 m x 2.1 m (3 ft x 3 ft x 7 ft)	12%–15%	~ 50 kg/linear m (~110 lb/linear ft)
Large round baleage	1.2 m x 1.2 m (4 ft x 4 ft)	55%	545 kg (1,200 lb)
Large round baleage	1.2 m x 1.5 m (4 ft x 5 ft)	55%	690–910 kg (1,500 lb)

Source: Clarke and Stone, OMAFRA, 2016.

[1] Bale weights will vary with moisture, density and grass-vs.-alfalfa content.

Usually, the first indication that the hay may be hot is the release of an odour similar to pipe tobacco and possibly steam rising from the mow. Hay temperatures can be monitored by using an electronic temperature/ moisture probe. The following temperature guidelines can be used for monitoring hay mows:

- 65°C — **Entering the danger zone.** Take temperatures daily.
- 70°C — **Danger!** Inspect every 4 hours to see if the temperature is rising.
- 80°C — **Fire pockets may form.** Call the fire department.
- 100°C — **Critical!** In the presence of oxygen, ignition will take place.

See the OMAFRA Publication 837 *Reducing the Risk of Fires on Your Farm* at ontario.ca/crops for more information.

Propionate Hay Preservatives

In order to manage the risks of rain-damage or mouldy hay resulting from hay that is baled before it is sufficiently dry, many hay producers are using commercially available buffered propionate (propionic acid) products. Getting that last increment of drying required is often difficult. Preservatives are particularly useful with higher density bales, such as large squares, that need to be drier at baling to avoid mould growth.

Propionate inhibits aerobic mould growth and subsequent heating while the bales "sweat' and "cure" down to safe moisture levels by dissipation and evaporation. Propionate hay preservatives should not be confused with enzyme, bacterial inoculant or nutritive additive products, which differ in modes of action and effectiveness. Hay preservative products are registered by the Canadian Food Inspection Agency (CFIA). Be sure to read the label, and follow application rates and directions. Propionate hay preservative products are now buffered to a pH of approximately 6.0, making them safer to use than the original unbuffered products. Products may also include acetic or citric acids. Treated hay is safe to feed to livestock. Propionate and acetate are organic acids that are also produced by microbes in the rumen (and the cecum and colon of horses) and then used by the animal as part of the digestion process.

Propionate preservative is sprayed onto hay as it enters the baler. Basic application systems include a tank, pump and nozzles. Adequate application rates according to moisture and bale type, and uniform coverage are important. The moisture content at baling determines the amount of preservative required, so it is important that moisture content be measured accurately. There can be large moisture differences within a swath. This variation can lead to pockets of wet material that will be inadequately treated. In manual systems, hand-held moisture probes may not be accurate enough to fine tune the moisture variability and amount of preservative needed, so adjust the rate to maximum rather than average moisture content. Automated computerized application systems are available that include in-chamber moisture sensors that automatically adjust application rates. These systems are common on newer large square balers. Proper indoor storage (off the ground on pallets or a layer of old hay with adequate ventilation) is critical to allow moisture to quickly dissipate out of propionate treated bales while in storage.

Hay Storage

As land value and production costs of haymaking go up and the price of hay increases, it is becoming increasingly important to preserve the hay value by using proper hay storage. Spoilage losses of hay stored outside on the ground are staggering. If the capital cost of a hay storage structure is amortized over 15–20 years, the added cost of production is typically much less than the potential losses from improper storage. Even when hay bales are placed inside, directly on concrete or gravel floors, they will spoil as moisture condenses on the bottom. Bales should be stored off the ground, by placing them on pallets, old hay, etc.

Tarping large round bales outside that are off the ground will reduce spoilage losses compared to having no protection at all. In a 1.5 m (5 ft) round bale, 19% of the hay is in the outside 8 cm (3 in.) and 36% in the outside 15 cm (6 in.). Bales placed directly on the ground will absorb moisture and spoil significantly. Bales should be kept off the ground by placing them on pallets, crushed rock, etc. Situate outside storage on a well-drained site. Bale tarps can be notoriously difficult to keep in place in stormy weather. In addition, after baling, insufficient ventilation under the tarp prevents humidity from escaping and can slow and impair curing. To prevent spoilage, large and small square bales should be stored inside a structure.

Remove bales from fields quickly to prevent damage from rainfall, absorbing moisture from the ground, and to minimize traffic damage to forage regrowth from machinery. To preserve quality, large square bales should be moved from the field the same day they are made.

Feeding Losses
Feeding losses of dry hay can be quite significant, with losses greater than 50% when hay is fed to cattle on the ground without a feeder. Cone and ring feeders have less waste than trailer or cradle feeders. Balers with pre-chamber cutting knives reduce feeding waste as less hay is pulled out of the feeder and trampled. As hay production costs increase, properly designed hay feeders that reduce waste can easily pay for themselves.

Horse Hay
The quality parameters for horse hay are quite different than for hay produced for cattle and sheep. Many horse owners determine the quality of hay primarily by a green colour that indicates the hay dried quickly and is free of mould, dust and weeds. Hay that is not adequately dry at baling will mould, which results in dusty hay that can cause significant respiratory problems in horses, as well as a risk of colic. Quality horse hay should not have been rained upon. Most horses do not require hay with high protein content, and many recreational horses have low energy requirements. A timothy-alfalfa mix is common. Horse hay can often be harvested later in the haying season when the plants are more mature, giving some flexibility in haying with less chance of being rained upon.

There is good market for horse hay in small square bales, as many horse owners do not have the equipment to handle large bales. There is also a quickly growing market for horse hay in large square bales for both domestic and export markets. Making quality horse hay in large square bales requires skills to ensure it is baled and stored dry enough to avoid mould and retain a green colour, but provides the advantage in increased capacity to produce much more volume of hay when the weather is suitable. More information on horse hay is available on the OMAFRA website at ontario.ca/crops.

Baleage (Large-Bale Haylage)
Large-bale haylage, or "baleage," produces a long-stem haylage by baling at higher moistures and wrapping the bales in plastic to make them anaerobic. While extra care is required to avoid mouldy feed, it is a flexible option for storing excellent-quality forage. Made correctly, baleage can be a very high nutrient quality, and palatable feed. By making baleage, a forage producer can be more aggressive and consistent in cutting schedules because it reduces the risk of rain-damage within shorter harvest windows. Many producers use baleage as their main storage system, but it can also be a flexible second system when the weather doesn't permit adequate drying or when the silos are full. Baleage makes use of existing hay equipment, such as large round and large square balers, and bale feeders. Heavier equipment and four-wheel-drive tractors may be required when handling the heavier bales.

The cost and disposal of the plastic are necessary considerations. The cost can usually be justified by the higher energy and protein value of the stored forage, reduced harvest losses, and the value of not requiring additional storage. Many municipalities offer bale wrap recycling programs. See the OMAFRA Factsheet *Recycling Farm Plastic Films* at ontario.ca/crops.

With baleage, there is less or incomplete fermentation relative to chopped haylage, and it does not have as low of a pH (a less acid environment). To prevent mould and spoilage, baleage relies on more of the forage being kept anaerobic (no oxygen) and requires covering it with adequate plastic. This results in less stable silage than conventional haylage. Storage time and length of time the bales are exposed to oxygen before feed-out should be adjusted to conditions.

Successful use of baleage involves the following management practices:

- Make firm, dense, uniform bales. Large squares are usually denser than rounds. Balers equipped with pre-chamber cutting knives produce bales that are denser.
- Bale at 40%–55% moisture. Too dry is preferable to too wet. Lower moisture baleage (25%–35% moisture) can work, particularly with large square bales, but are at a greater potential risk of spoilage. It is essential that bales are covered with additional plastic and kept "air tight".
- Use enough plastic! Bales should be wrapped air-tight with a least 6 mils of plastic film. To ensure against tears, 8 mils or more is preferable, particularly with drier baleage.
- Wrap round bales within 2 hours of baling on hot days and within 4–12 hours at cooler temperatures. Large square bales are more forgiving of later wrapping.
- Avoid using hay that was rained on.
- Do not incorporate soil into the windrow by raking in contact with the ground. This can contaminate the forage with *Clostridia* bacteria

that will negatively affect fermentation. Avoid fields where manure has been applied since the previous cut.
- Avoid mature hay with low sugar content.
- Early-cut grass is typically easier to make into baleage than alfalfa.
- Be sure to monitor and repair all tears and holes in the plastic.

Haylage and Corn Silage

Storing forage as hay-crop silage or "haylage," has advantages over storing it as hay. These advantages include:

- lower harvest losses
- greater capacity for a faster harvest of more acres
- less dependence on good drying conditions, which allows the crop to be cut at the desired maturity

Corn silage is a popular forage crop due to yield, palatability, high-energy density and single harvest convenience.

Silage Crop Storage Types

The most common types of silage storage are:

- vertical (tower) silos: conventional, oxygen limiting (sealed)
- horizontal silos: bunker, piles, silage bags
- large bale haylage (baleage)

When to Harvest Corn Silage

Harvesting corn silage at the correct moisture is critical for feed quality. The best livestock performance and corn silage fermentation usually occur when whole plant moisture is 65%–70%. This corresponds well to horizontal and bag silos, but silage may have to be somewhat drier in tower silos to prevent seepage, see *Maintain Correct Moisture Content*.

Kernel Milk Line

The kernel "milk line" has been used in the past to determine when to harvest corn silage, but this method has limitations. The technique involves breaking a cob in half and looking at the kernels. After denting (0% milk line), a whitish line can be seen on the kernels. This line is where the solid and liquid parts of the kernel are separated while maturing and drying. This line will progress from the outer edge of the kernel to the cob. When this milk line reaches the cob (100% milk line), a black layer is visible. The traditional standard has been to harvest between one-half to two-thirds milk line.

Corn plants severely stressed by dry weather without cobs do not have kernel milk lines to use as estimates, but are typically much higher moisture than they appear. Similarly, it can be difficult to accurately estimate whole-plant moisture from kernel milk lines in frost-damaged corn. Hybrid differences also affect the accuracy of using kernel milk line to estimate moisture level. Corn hybrids have varying degrees of "stay-green" characteristic. More stay-green means there is faster grain dry-down relative to stover dry-down. This is desired in a grain hybrid, because, as the grain dries, the stalk stays green and healthy, and is less likely to have broken stalks and lodge in late season. Some hybrids are designed only for use in silage and have less stay-green, so that the grain will have higher moisture relative to the whole plant. In other words, hybrids with higher stay-green ratings will have milk lines that are more advanced relative to whole plant moistures. Silage-only hybrids that have less stay-green characteristic will likely be ready to harvest at a less advanced milk line. Check with your seed company representative for historic milk line recommendations for estimating moisture levels in a given hybrid.

Measuring Percent Moisture

The most accurate method of determining when to harvest silage corn is to directly measure the moisture content.

1. Sample at least 10 plants from the field, avoiding the headlands. Watch for moisture variability within fields.

2. Chop a sample using a harvester or yard chipper. The finer the sample is chopped, the easier it will be to dry and the more accurate the result.

3. Use a commercial forage moisture tester, microwave or laboratory to determine the percentage of dry matter. Moisture testers and microwaves may not remove all the residual moisture in the sample and may underestimate the moisture level by about 2%–3%. The most accurate option is to send a sample overnight delivery to a forage laboratory for oven drying.

Shortly after denting, when the milk line is about 20%, whole plant moisture can be determined. In a typical year, corn silage at this stage dries approximately 0.5% per day. Therefore, if the sample was 70% moisture, and 65% moisture is the target, harvest should be done about 10 days after the corn was sampled. In dry years, the drying rate will be more rapid; in wetter years, the drying rate will be slower. Moistures can be checked again closer to harvest if necessary.

Calculating approximate days to reach target moisture: 70% current moisture – 65% target moisture = 5% ÷ 0.5% drying/day = 10 days

Silage Fermentation

When forage is first put into a silo, conditions are aerobic (oxygen is present in the silage). Plant respiration and aerobic bacteria convert carbohydrates into carbon dioxide, water and heat, and use up the oxygen present. This phase should be as short as possible.

The silage then becomes anaerobic (without oxygen). The growth of anaerobic bacteria ferments sugars to organic acids (primarily lactic and acetic acid) and other products, including carbon dioxide, heat and water. This biological conversion from fresh plant material to fermented silage also results in the "shrink" or fermentation losses of dry matter and energy. A fast, efficient fermentation that is dominated by lactic acid bacteria (LAB) producing primarily lactic acid, reduces these losses to a minimum. In 2–4 weeks, the silage reaches a stable pH of 3.8–4.5, and all bacterial and enzymatic activity stops. Once this stable pH has been reached, further breakdown of nutrients and spoilage is prevented, and the silage will keep for extended periods of time, provided air (specifically oxygen) is excluded.

Silage Storage Losses

Respiration Losses

When plants are harvested and ensiled, the plant cell respiration continues, resulting in a breakdown of sugars and other carbohydrates. Faster wilting and silo filling minimizes these losses.

Fermentation Losses

Good silage management is aimed at minimizing this potentially significant loss in dry matter and energy, commonly known as "shrink". This reduces both yield and nutrient quality. A poor or extended fermentation results from the following factors and will increase losses:

- slow filling
- poor packing
- poor covering
- improper harvest moisture, or
- lack of a suitable LAB inoculant

Seepage Losses

When excessively wet material is put into a silo, moisture can "squeeze" from the silage. The seepage carries sugars and other nutrients out of the silo. In addition, seepage can lead to excessive corrosion of the silo walls and result in the possible collapse of the silo. Silo seepage can also lead to fish kills if it enters a watercourse, see the OMAFRA Factsheet, *How to Handle Seepage From Farm Silos* at ontario.ca/crops.

Heating

Heating causes plant sugars and proteins to combine and form indigestible compounds. This results in a "toasting" or browning of the silage and reduced protein digestibility. In extreme cases, because the silage is too dry or a continuous supply of air is getting into the silage, spontaneous combustion can lead to a silo fire. Such fires can happen at any time of the year and are almost impossible to extinguish.

Surface Spoilage

Covering and sealing horizontal silos quickly is essential to avoid spoilage and dry matter loss from both oxygen exposure (the growth of yeast, moulds and aerobic bacteria) and rainfall that washes organic acids and soluble nutrients from the silage. Dry matter losses can be 30% or more with an uncovered silo.

Feed-Out Losses

When a silo is opened to remove feed, there can be significant further losses of dry matter and feed nutrient value, as well as spoiled feed. These losses are caused by moulds and yeast that become active in the silage when it is again exposed to oxygen. Secondary losses can occur at the silo surface and in the bunk while being fed. Minimizing the time exposed to oxygen by proper face management and feed-out rates is important.

Recommended Silage Management Practices

Maintain Correct Moisture Content

- conventional upright silos: 60%–65%
- horizontal silos: 60%–70%
- oxygen-limiting silos: 50%–60%
- bag silos: 60%–70%
- wrapped large bale haylage: 40%–55%

Quickly Fill and Pack Horizontal Silos

Silage that is too dry will result in poor packing and air exclusion, poor fermentation and the production of heat. Silage harvested at moisture percentages greater than 70% can result in seepage and an undesirable clostridia fermentation that results in butyric acid formation, high dry matter losses and poor feed quality, palatability and intake potential.

Use Proper Length-of-Cut

Fine chopping helps to exclude air by allowing tighter packing density, but must be balanced with proper physically effective fibre (peNDF) for proper rumen function requirements. The actual particle length will be different from the theoretical length-of-cut (TLC) and can be checked with a particle length separator.

With haylage, a 10 mm (0.4 in.) TLC is generally suggested. Low moisture silage may require a shorter TLC to ensure adequate packing. The length of cut is often more critical with horizontal silos, although it is still important with upright and sealed silos. Harvester blades must be sharp and correctly set. Chopping too fine does not improve packing, requires more horsepower and low peNDF can result in nutritional problems.

Corn silage "kernel processors" use rollers attached to the chopper to break cobs, crack kernels and shred stalks. The TLC suggested with processors is 19 mm (0.75 in.) rather than 10 mm (0.4 in.) without a processor. Processors are especially beneficial in increasing starch digestibility in relatively dry, hard-kernel, textured corn.

Packing is typically the weakest link in bunker silo management. Dense packing reduces dry matter losses, yeast and mould growth, heating problems and storage costs. Packing density goals are at least 272 kg/m^3 (17 lb/ft^3) dry matter for corn silage and at least 240 kg/m^3 (15 lb/ft^3) for haylage.

Filling silos as rapidly as possible reduces silage exposure to air and rainfall. Bunker silos should be filled from back to front so that a "progressive wedge shape" (1:4 slope) is created, rather than filling from bottom to top. Pack in thin layers of no more than 15 cm (6 in.) in order to get good air exclusion and high silage density. Sufficient tractor weight and packing time are critical. This may mean using a larger tractor, or adding more packing tractors to increase packing time per tonne. Be sure to take precautions to prevent tractor rollovers.

Seal Silos Well

Covering and sealing with UV-protected silage grade 6 mil–8 mil white plastic is essential in horizontal silos. The plastic should be held firmly in place to keep air from moving under the plastic into the silage. Avoid situations where plastic flaps and acts like a bellows to increase air circulation over the surface rather than excluding it. Old tires (split) placed closely together (touching) work very well. An alternative is a commercially available system of nylon bags filled with sand or gravel. Sealing the plastic edges can be done with soil, aglime or sandbags. Don't put sandbags on the wall, because with "shrink" there will be an air gap under the plastic.

Photo 3–4. Covering and sealing silage from air and water helps reduce silage spoilage.

It is important to prevent rainfall runoff from flowing between the silage and bunker walls. Silage at the bottom corners of the pile and against the wall is often too wet, resulting in butyric acid that results in poor palatability, high spoilage losses and subclinical ketosis in dairy cows. Shape the pile and place plastic so that rainfall runs off and away from the silage, rather than down the walls.

Allow Complete Fermentation

Silage fermentation requires a minimum of 3 weeks or more. To ensure silage stability and maximize feed bunk life, do not feed out of the silo until this process is complete.

Feed Out Quickly to Minimize Spoilage

The re-exposure of the silage to air at feed-out can result in the growth of moulds, yeast and aerobic bacteria. Slower feed-out rates increase the likelihood of aerobic spoilage. During hot, humid weather, larger feed-out rates are required to stay ahead of the spoilage. Size silos accordingly. Empty tower silos at a rate of at least 5 cm (2 in.) per day in winter and 7–10 cm (2.75–4 in.) per day in summer. Horizontal silos should be fed out at a minimum rate of 10–15 cm

(4–6 in.) per day, depending on the season. Feed-out rates may have to be twice that in hot summer weather to avoid significant spoilage. Feeding mouldy silage is not recommended because it reduces intake and can cause nutritional problems.

Manage Silage Face to Minimize Spoilage

The silage face should remain tight and smooth to limit the penetration of air. Block cutters or shear buckets are excellent options. Avoid fracturing the silo face by running at it with a front-end loader and using a lifting action. Minimize fracturing by scraping down the face with the front-end loader and allowing the silage to fall to the floor. Uncover and loosen only as much silage as is required.

Silage Inoculants

Silage inoculants are used to manipulate and enhance fermentation in haylage (alfalfa, grass, cereals), corn silage and high moisture corn. These inoculants contain "homofermentative" lactic acid producing bacteria (LAB) and other bacteria, such as *Lactobacillus buchneri*. The goals are faster, more efficient fermentation with reduced fermentation losses, improved forage quality and palatability, longer bunk life, and improvements in animal performance.

Species and specific strains of bacteria in commercial inoculants have been selected to grow rapidly and efficiently, increasing the fermentation rate with a more rapid decline in pH. Reduced fermentation losses are the result of a more efficient fermentation to lactic acid, with less acetic acid and ethanol, and less carbon dioxide produced that is lost to the environment. Assuming that if fermentation dry matter losses are reduced by a modest 3%, an inoculant could easily pay for itself by reduced shrink alone, before potential improvement in animal performance and bunk life are even considered.

LAB inoculants are typically more successful in alfalfa and grass silage, than in corn silage. Corn silage has a higher sugar content and lower buffering capacity, allowing an easier fermentation. While most corn plants at harvest time are covered in naturally occurring LAB, corn silage harvested after a killing frost should benefit from using an inoculant.

Corn silage inoculants containing both LAB and *Lactobacillus buchneri* are "heterofermentative." These produce lactic acid earlier in the fermentation to reduce fermentation losses, and then acetic acid later in the fermentation to improve aerobic stability by staying fresher longer at feedout. The acetic acid reduces the growth of yeasts and makes the silage more resistant to spoilage and heating at feed out. In situations where spoilage at feedout is an issue, the use of *Lactobacillus buchneri* inoculant on corn silage may result in less mould and mycotoxins, improved palatability and intake, and reduced total dry matter losses.

Enzyme additives are sometimes included in some inoculant products, including cellulases, hemicellulases and amylases to help break down cellulose, hemicellulose and starch. Research results are mixed and inclusion rates need to be sufficient for desired results. Some newer inoculants contain bacteria that have been selected to produce their own enzymes to improve fibre digestibility and subsequent digestible energy and intake.

Forage additives, including silage inoculants, must be registered with the Canadian Food Inspection Agency (CFIA) to be sold in Canada. Ask company representatives to provide independent research that substantiates the claims for the product, and for product quality control assurances. It is important that the product is labelled for the crop being ensiled, and that directions for storage and use are followed. The application of a silage inoculant will not overcome the effects of poor silage management or poor weather conditions.

Common Silage Problems, Causes & Diagnosis

Common Silage Problems

- Rancid, Fishy Odour
  A rancid, fishy odour is butyric acid resulting from clostridia contamination from soil. Clostridia silage can result from cutting or raking too close to the ground, soil from packing tractor tires, "splash" from rain, or manure applied too late after the previous cutting. Butyric acid also commonly results from silage that is too wet (>70% moisture). As well as its foul odour, this silage sometimes has a slimy, sticky texture that clump into "butryic balls". Fermentation losses are high, so ADF levels are high and protein is degraded. Palatability, intake, and digestible energy are low, and livestock performance is poor.
- Mouldy With A Musty Odour
  Mouldy silage results in high dry matter losses, as well as poor palatability and livestock performance. This spoilage is the result of aerobic (oxygen) conditions from poor packing, slow filling, low moistures, poor sealing, slow feedout, or poor face management. If the silage is still hot, microbial activity and spoilage is still underway.

- Vinegar Odour
  A vinegar odour indicates acetic acid. Too much acetic acid relative to lactic acid means the fermentation was less than optimally efficient, and possibly could have benefited from a commercial lactic acid bacteria (LAB) inoculant.
- Sweet Odour
  A sweet smell is likely high concentrations of ethanol produced by spoilage yeasts, mixed with acetic acid. Fermentation losses were likely high and this silage will be prone to heating and spoiling in the bunk. Desirable lactic acid has little smell.
- Ammonia Odour
  An ammonia odour indicates excessive protein breakdown to ammonia and amines, which could be due to a clostridia fermentation or high pH.
- Caramelized Odour
  The caramelized odour indicates heat damaged haylage which is dark in colour with a tobacco-like odour. In severe cases it can smell burnt. It is the result of forage that is too dry. Protein becomes bound and is less digestible. ADF-N (unavailable nitrogen) can be measured in a laboratory.

Fermentation Analysis

A newer technology used in silage problem-solving is fermentation analysis. It objectively quantifies what people subjectively see and smell. This can be especially useful when poor livestock performance cannot be explained by nutrient analysis. Typical fermentation end product concentrations are listed in Table 3–12, *Typical levels of silage fermentation end-products (dry matter basis).*

Fermentation end-product concentration varies in different types of silage and includes:

1. High pH
   A high pH indicates a poor or restricted fermentation that will be less stable and result in poor bunk life and more spoilage at feeding. Legume haylage has a higher buffering capacity than grass haylage and corn silage, and usually has a higher pH.

2. Low Lactic Acid
   Lactic acid should be greater than 65%–70% of the total silage acids, with a lactic/acetic acid ratio of at least 3:1. Lactic acid is the most effective in lowering pH.

3. High Acetic Acid
   Acetic acid levels greater than 3%–4% can result from poor fermentations, especially if lactic acid levels are significantly low. Buchneri inoculants are sometimes added to corn silage and high moisture corn to produce acetic acid late in the fermentation to improve bunk life. This should not be mistaken for poor fermentation.

4. High Ethanol
   High ethanol indicates yeast that reduces dry matter recovery and makes the silage more prone to mould and feedout spoilage.

5. High Ammonia-N
   This indicates excessive protein breakdown and possibly excess ruminally degraded protein. Levels greater than 12%–15% can be a problem.

6. Butyric Acid
   Butyric acid in forages reduces quality. If butyric acid is accompanied by high percent moisture and/or high ash content, then this will determine what management issues need to be corrected. In the silo, butyric acid results in high losses of dry matter and digestible energy. In the ruminant it results in poor intakes and metabolic problems. If possible, silage high in butyric acid should be discarded. Dr. Gary Oetzel, University of Wisconsin, suggests

Table 3–12. Typical levels of silage fermentation end-products (dry matter basis)

Fermentation End Products	Corn Silage	Legume Haylage >65% moisture	Legume Haylage <55% moisture	Grass Haylage
pH	3.7–4.2	4.3–4.5	4.7–5.0	4.3–4.7
lactic acid %	4–7	7–8	2–4	6–10
acetic acid %	1–3	2–3	0.5–2.0	1–3
propionic acid %	<0.1	<0.5	<0.1	<0.1
butyric acid %	0	<0.5	0	0.5–1.0
ethanol %	1–3	0.5–1.0	0.5	0.5–1.0
ammonia-N (% of CP)	5–7	10–15	<12	8–12

Source: Dr Limin Kung, University of Delaware.

the following butyric acid daily limits to prevent off-feed and ketosis in dairy cows:

- fresh cows – <50 grams
- early lactation – <150 grams
- all other lactating cows – <250 grams

Silo Gas

Producers exposed to silo gas (nitrogen dioxide or NO_2) are at risk of severe respiratory distress, permanent damage to lungs, and even sudden death. It is difficult to predict when silo gas will be produced, so always take precautions following harvest. Weather conditions and agronomic practices affect the amount of nitrates in plant material, which sets the stage for the production of NO_2 in the silo. For example, a dry period during the growing season followed by abundant rainfall will encourage a corn crop to take up high levels of dissolved nitrates. If the corn is harvested before the nitrates can be converted to proteins, nitrogen dioxide is produced.

Silo gas is produced almost immediately after filling a silo. The greatest risk is the first 12–60 hours after filling the silo, and then risk declines for approximately 4–6 weeks until silage fermentation is complete. Silo gas has a bleach-like odour and may be visible as a reddish-brown haze. However, it is not always visible. Nitrogen dioxide is heavier than air; therefore, it tends to be located just above the silage surface. It may flow down tower silo chutes and into feed rooms. Tower silos are at greater risk because the silo gas is contained at the silage surface level, and operators often enter the silo after filling to level silage and set up the unloader.

When inhaled, nitrogen dioxide mixes with body moisture to form nitric acid, which causes severe burning of the lungs and the rest of the respiratory system. Pulmonary edema often occurs resulting in victims collapsing. Other people can also be overcome when they attempt a rescue. Producers exposed to silo gas should get immediate medical attention.

When entering a silo:

- Do not enter a silo during the risk period without wearing an appropriate self-contained breathing apparatus.
- Before entering the silo, ventilate it by running the forage blower for 30 minutes and leave it running while inside.
- Also ventilate the silo room and chute.
- Post appropriate warning signs.
- Keep people and animals away.

For more information on preventing injury or death from silo gas, refer to:

Silo Safety — Workplace Safety and Prevention Services at www.wsps.ca.

See the OMAFRA Factsheet, *Hazardous Gases on Agricultural Operations* at ontario.ca/crops.

Other Crop Problems

Insects and Disease

Severe infestations of disease and insects that result in reduced stand vigour, reduced root reserves and slow regrowth will increase the risk of winterkill. Potato leafhopper control can be important in reducing winterkill, particularly in the seeding year. See Chapter 15, *Insects and Pests of Field Crops, Potato Leafhopper*.

Figure 3–3, *Forage scouting calendar*, shows insects and diseases that could be causing the symptoms in the field. Individual descriptions of insects and diseases, scouting and management strategies can be found in Chapter 15, *Insects and Pests of Field Crops,* and Chapter 16, *Diseases of Field Crops.*

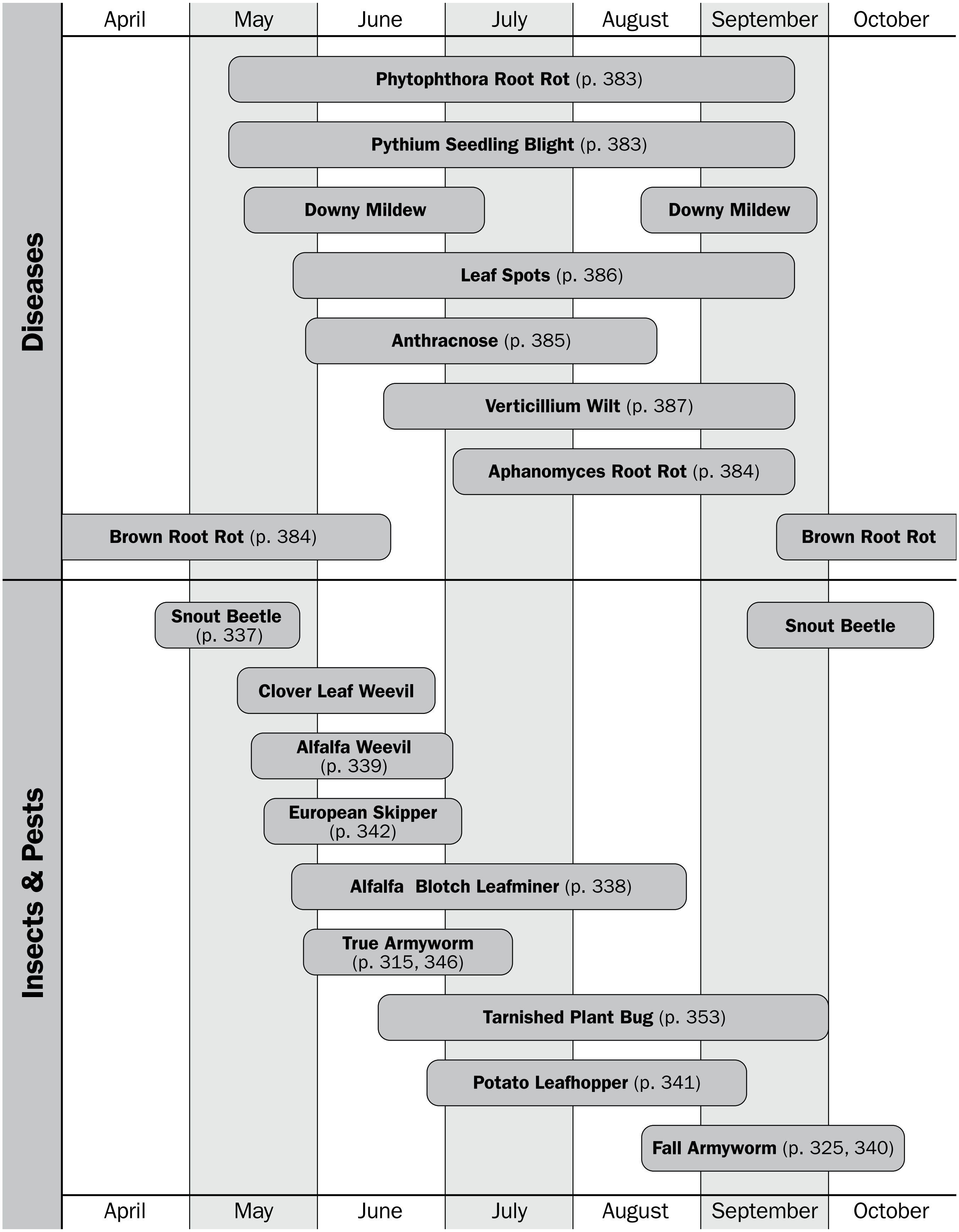

Figure 3–3. Forage scouting calendar.

Treatments to control insects, pests and diseases can be found in OMAFRA Publication 812, *Field Crop Protection Guide.*

Forage Winterkill

Winterkill of forage stands can cause serious problems on livestock farms and can be a limiting factor in alfalfa production. It can result in lower-quality feed, shortages of feed, disruption of the rotation and additional costs for reseeding lost stands. With forage production, it can sometimes be difficult to optimize the competing demands of quality, yield and persistence. Determine how much forage persistence is needed and manage the risks accordingly.

Factors that contribute to the risk of forage winterkill include:

- smothering due to flooding or ice sheet formation
- heaving caused by freezing and thawing and inadequate drainage
- crown injury due to low temperature
- low fertility
- old stands
- cutting management
- diseases and insects

Some forage species are hardier than others. Much of the concern over winterkill centres around alfalfa. The legumes birdsfoot trefoil, red clover, wild white clover and alsike will tolerate more adverse winter conditions than alfalfa or ladino clover. The grasses timothy, reed canarygrass, bluegrass and bromegrass rarely winterkill; thus, their use in mixtures gives stands insurance. Orchardgrass and perennial ryegrass are more likely to be killed by icing or low temperatures.

Hardening is the process of cold tolerance development initiated by shorter autumn days and cooler temperatures. During the hardening process, plants store carbohydrates in crowns and taproots. The starch is converted to sugars, which gives the plants some protection from freezing. Plants also lose some cellular water to reduce freezing damage. Long fall periods with cool, dry, sunny conditions favour winter hardening.

Factors That Affect Winter Survival

Critical Fall Harvest Period for Alfalfa

While cutting alfalfa in the fall is often practiced in Ontario, it can increase risk to stand health, depending on the location, stand age, harvest frequency and other factors. The decision whether to cut alfalfa in the fall should weigh these factors and the immediate need for forage against the increased risk of winterkill and reduced yields the following year.

Harvesting before the critical fall harvest period for alfalfa, also known as the “fall rest period,” allows the plants to regrow and build sufficient root energy reserves for over-wintering. Adequate root reserves are necessary for winter survival and persistence, as well as for vigorous spring growth and good first-cut yields. The critical fall harvest period for alfalfa is the 6-week period preceding the average historical date of killing frost. However, it is difficult to predict when that killing frost will actually occur. The actual date seldom occurs on the average date, so these are guidelines only. When cut early in the period, the alfalfa will use the existing root reserves for regrowth, “emptying the tank”. Later in the period, the alfalfa uses photosynthesis to produce carbohydrates and stores them as root reserves, “refilling the tank”. Cutting in the middle of the critical period (third or fourth week) is a higher risk than cutting at the beginning or end of the period. See Figure 3–4, *Start of the critical fall harvest period for alfalfa,* to determine the critical fall harvest period in different regions of Ontario. See the OMAFRA Factsheet, *Risk of Alfalfa Winterkill,* at ontario.ca/crops. Birdsfoot trefoil, similar to alfalfa, has a critical fall harvest period, beginning about 10 days earlier than alfalfa.

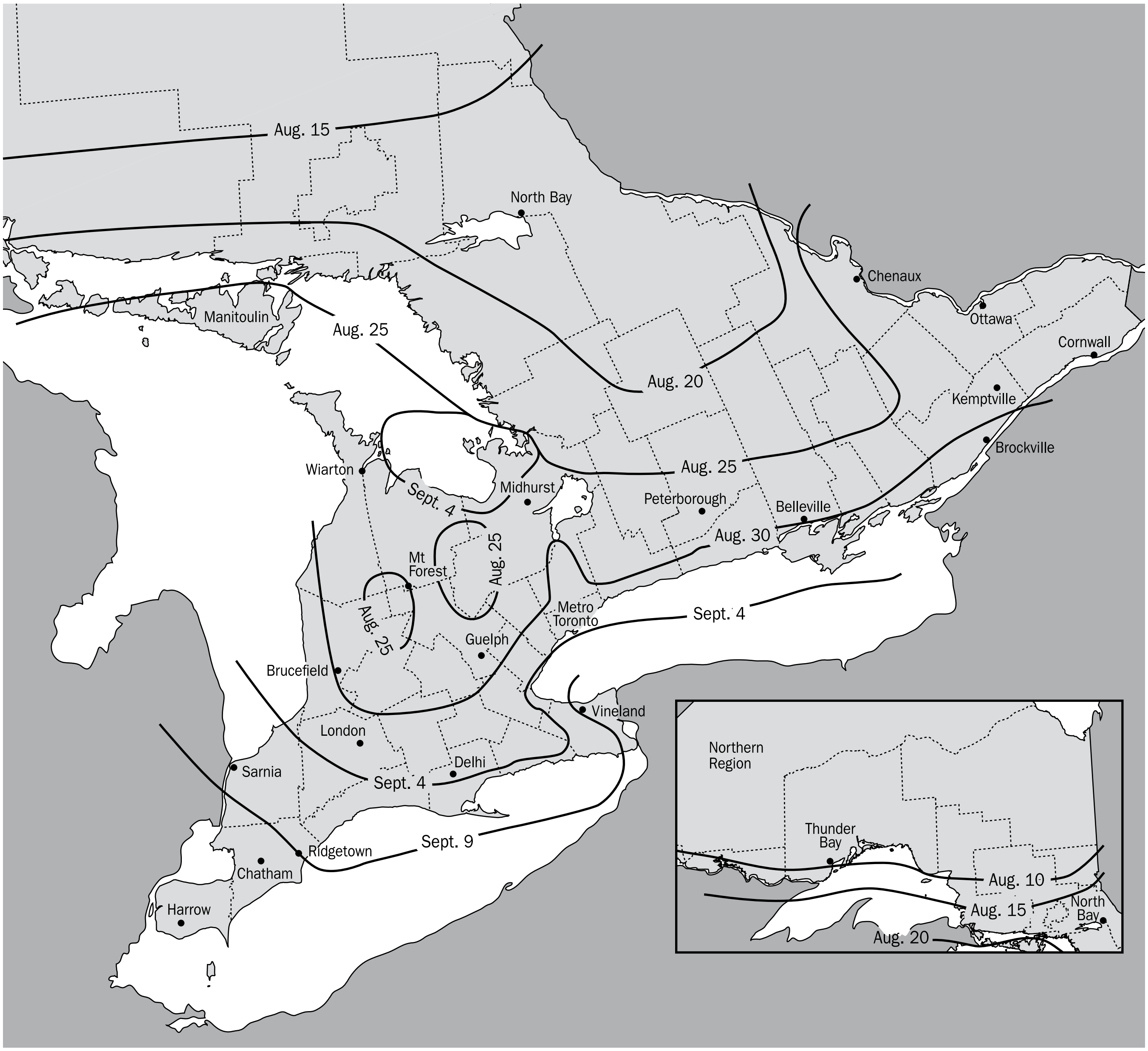

Figure 3–4. Start of the critical fall harvest period for alfalfa.

Management Risk Factors

Some areas of the province, such as the Ottawa Valley and New Liskeard have a higher historical risk of alfalfa winterkill. Flat, heavier soils that "pond" in the winter when frozen soils prevent infiltration to tiles are at greater risk of winterkill. Wet saturated soils in the fall reduce winter hardening and contribute to winterkill. Aggressive cutting schedules with cutting intervals of less than 30 days between cuts increases the risk of winterkill, while intervals over 40 days (allowing flowering), reduce the risk. Disappointing first cut yields from the location from which fourth cut was taken the preceding fall are sometimes observed.

In addition, fields with the following qualities are also at increased risk of winterkill and are poor candidates for fall harvesting (unless rotation to another crop is planned):

- older stands (3 years or greater)
- low potassium soil tests (<100 ppm)
- low pH (<6.5)
- poor soil drainage
- insect pressure (potato leafhopper)
- disease (root and crown rots)

Late Fall Cuttings at the End of the Critical Fall Harvest Period

If fall harvesting an alfalfa forage, the risk of winterkill can be reduced, but not eliminated, by cutting towards the end of alfalfa growth, close to a killing frost. Few root reserves will be depleted by regrowth, but lack of stubble to hold snow to insulate the alfalfa crowns against cold weather damage and heaving may be a problem. Leaving at least 15 cm (6 in.) of stubble will help. Stubble will also protrude through winter ice sheeting, allowing air to move below the ice. Limit late cuttings to fields that are otherwise lower risk — well drained, good fertility, healthy crowns and roots, etc. A killing frost occurs when temperatures reach -4°C for several hours. After a killing frost, alfalfa feed value will quickly decline, as leaf loss occurs and rain leaches nutrients. Heavy stands of grasses or red clover can sometimes smother or die from disease over the winter because the top growth forms a dense mat. In contrast, alfalfa loses most of its leaves as soon as there is a hard frost, and the remaining stems remain upright and seldom pose a risk of smothering.

Weather Risk Factors

Adequate snow cover of at least 15 cm (6 in.) insulates the alfalfa crown and root at moderate temperatures. A lack of snow cover can expose alfalfa crowns to temperatures less than –15°C. This results in freezing damage to plant cells and eventual plant death. The insulation effect from snow also reduces soil temperature fluctuations and risk from heaving. Fluctuating winter temperatures with lows below freezing and extended highs greater than 5°C, without snow cover, can cause plants to break dormancy and become more susceptible to freezing.

Fast melting of snow followed by cold temperatures can result in ice sheeting, which smothers the plants by restricting oxygen. Ice sheeting also causes freezing damage to alfalfa crowns, due to the poor insulating ability of ice.

Frost Heaving of Alfalfa

Repeated freezing and thawing cause the taproot to be pushed out of the soil (Photo 3–5). Plants may initially green-up and appear undamaged, but taproots heaving more than 2.5 cm (1 in.) are typically broken and unable to pick up enough nutrients or moisture, and stands eventually die or become severely stunted. Slightly heaved plants can survive, but their longevity and productivity will be reduced. Alfalfa stands with significant frost heaving should be rotated to another crop and replaced with a new seeding in the rotation.

Photo 3–5. Alfalfa heaving is caused by freeze/thaw cycles of early spring, lifting up the crown.

Assessing an Alfalfa Stand for Winter Survival

Future yield potential can be estimated by counting the number of plants or stems for a given area, but the health of crowns and roots is extremely important. Stem counts are more accurate than plant counts, but in early spring it may only be possible to count the number of crowns. Be prepared to replace an older stand if it has less than 43 plants/m^2 (4 plants/ft^2). See Table 3–13, *Desirable alfalfa stand plant count* and Photos 3–6 and 3–7.

Dig several plants to determine the health of the crown and root. Healthy crowns are large and symmetrical and have many shoots. Cut a root open lengthwise. Healthy roots will have a white or creamy colour inside, and are firm and resistant to pealing when scratched with a thumbnail. Dying plants will have a discoloured crown and root and a spongy texture. Check for bud or new shoot vigour.

When alfalfa is about 15 cm (6 in.) in height, stems/m^2 (stems/ft^2) can be used as the density measure. Stem density of 590 stems/m^2 (55 stems/ft^2) has good yield potential, see Figure 3–5, *Alfalfa yield potential at various stem count densities*. There may be some yield loss with stem counts between 431–539 stems/m^2 (40–50 stems/ft^2).

Photo 3–6. Stand assessed with less than 5 plants per square foot due to winterkill.

Photo 3–7. Forage stand with winterkill has enough plants to remain in production.

Table 3–13. Desirable alfalfa stand plant count

Age of stand	Plant Count
New seeding	215 plants/m^2 (20+ plants/ft^2)
Year 1	129–215 plants/m^2 (12–20 plants/ft^2)
Year 2	86–129 plants/m^2 (8–12 plants/ft^2)
Year 3 or older	54 plants/m^2 (5 plants/ft^2)

Consider replacing the stand if there are less than 430 stems/m^2 (40 stems/ft^2) and the crown and root health is poor.

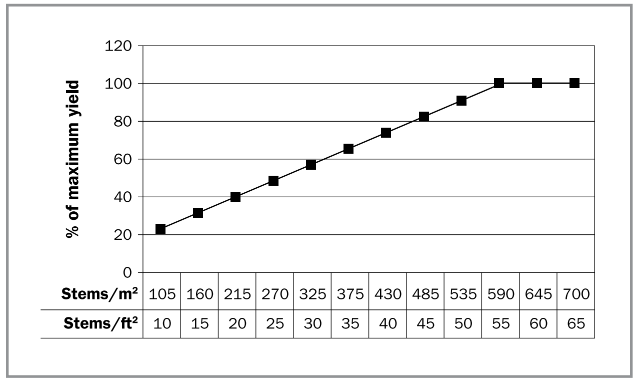

Figure 3–5. Alfalfa yield potential at various stem count densities.

Source: Undersander and Cosgrove, University of Wisconsin, 1992

Options Following Alfalfa Winterkill

If alfalfa winterkill is identified early, the best option is usually to replace the winterkilled stand by seeding a new forage stand in a new field in the crop rotation. Growing corn in the winterkilled alfalfa field allows the utilization of a 110 kg/ha (100 lb/acre) nitrogen credit, in addition to the 10%–15% yield benefit that corn receives following alfalfa in the rotation. Cereals and cereal-pea mixtures can be grown as a forage silage crop, either as a companion crop to a forage underseeding, or on their own. If planted early in the spring with adequate rainfall, these cool-season crops grow rapidly to help replace the loss of winterkilled first-cut alfalfa. If an alfalfa stand is uniformly thin or weakened, but the grass content is good, the application of nitrogen (N) can significantly increase grass yields as well as the forage protein level. Where winterkilled areas are large and patchy, some producers prefer to attempt to repair these areas by no-tilling in red clover and/or Italian ryegrass. When the winterkill is not identified until later in the spring, warm-season annual forage crops, including sorghums, sorghum-sudans, BMR sorghums, and pearl millet, can yield very well and provide forage earlier in the season than corn silage, but are lower yielding than corn silage.